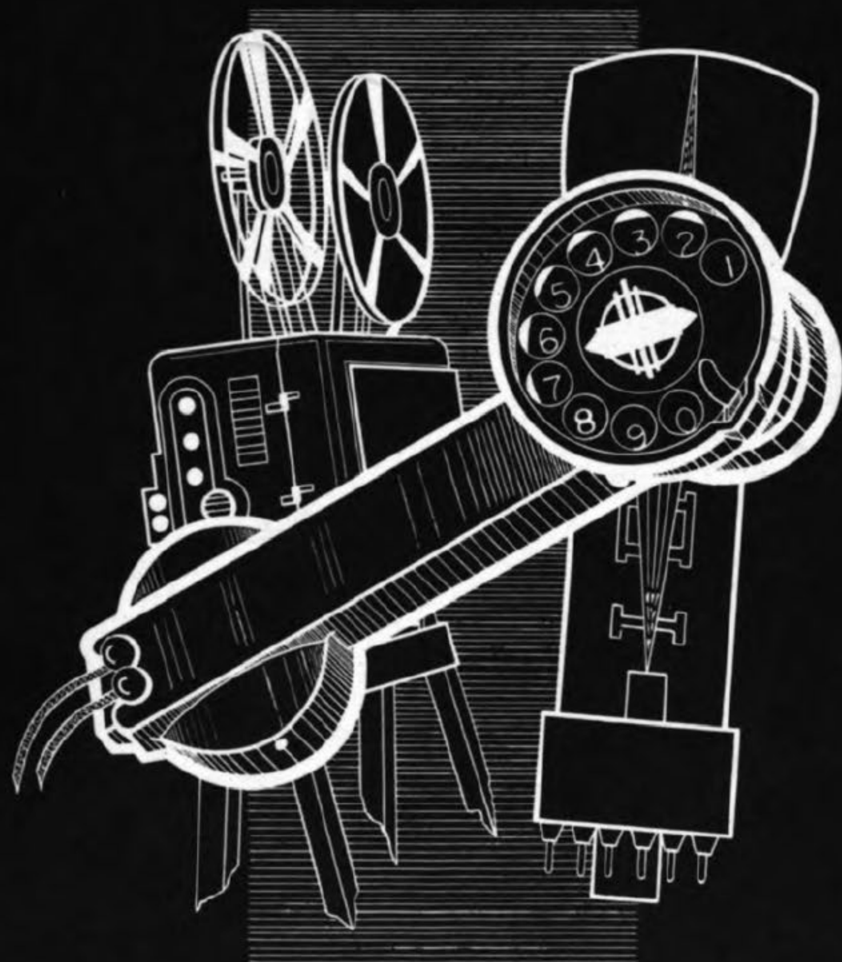

IC ELECTRICIAN 2

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10556-A

PREFACE

This book is written for men of the U. S. Navy and Naval Reserve who are qualifying for advancement to I. C. Electrician 2. Combined with the necessary practical experience, this training course will prepare the reader for the advancement-in-rating examination.

The qualifications for I. C. Electrician are listed in appendix II. This training course contains information on each knowledge factor of the qualifications for I. C. Electrician 2. Because examinations for advancement are based on these qualifications, interested personnel should refer to them frequently for guidance.

I. C. Electrician 2 was prepared by the U. S. Navy Training Publications Center, Washington, D. C., which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by Navy activities cognizant of shipboard electrical equipment and the duties of I. C. Electricians.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

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<tr><td>24</td><td>14 days</td><td>14 days</td><td>14 days</td><td>14 days</td><td>28 days</td><td>42 days</td><td>56 days</td><td>28 days</td></tr>
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</table>

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

Basic Hand Tool Skills, NavPers 10085 (Metal Working Skills Only).
Basic Electricity, NavPers 10086
Basic Electronics, NavPers 10087 (less chapters 14)
I.C. Electrician 3, NavPers 10555-A

OTHER PUBLICATIONS

Bureau of Ships Technical Manual, Chapters 4, 31, 45, 60, 61, 62 (sections I and II), 63, 64, 65, 66, 69, 85, and 88 (section II, Part 8 and section III).
U. S. Navy Safety Manual OP Nav 34P1 Ch 18

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer*. The following is a partial list of those courses applicable to your rate:

SELF-TEACHING

Number	Title
MA 784	Electric Wiring
MB 290	Physics I (Mechanics)
MB 785	Electrical Measuring Instruments
MB 858	The Slide Rule

CORRESPONDENCE

CB 290	Physics I (Mechanics)
CB 785	Electrical Measuring Instruments
CB 858	The Slide Rule

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

CHAPTER 1

NEW CHALLENGES

INTRODUCTION

This training course is intended to aid the I.C. Electrician 3 in preparing for advancement to I.C. Electrician 2. Through the study of this manual along with the development of his technical skills and administrative abilities, an IC3 can prepare himself for a successful and rewarding naval career.

The Navy through its promotion system offers many opportunities for advancement. These advancements are earned only by extra effort and study. The compensations, however, are many. The work is more challenging, the pay is better, and authority and prestige are increased.

RATING STRUCTURE

The enlisted rating structure described in the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Revised), is the primary means for the classification of Navy enlisted personnel. It is a systematic alignment of occupational groups (rates and ratings). The rating structure is subject to a continual review to ensure the most effective manpower utilization and career patterns.

The rating structure established in 1957 has replaced the old rating structure established in 1947. The concept of the broadly trained and qualified petty officer is retained in the new structure, and at the same time, effective manpower utilization is ensured by providing the desired specialization in the lower pay grades of certain ratings. The revision also provides for an integrated structure applicable to both the regular Navy and the Naval Reserve, which undergoes no basic change upon mobilization. The new rating structure consists of (1) general ratings, (2) service ratings, and (3) emergency ratings.

The general rating reflects qualifications in all aspects of an occupational field and ensures broadly qualified senior petty officers. A general rate is a pay grade level within a general rating. General rates will exist in pay grades E-6 and E-7 of all general ratings, and in the lower petty officer grades in those ratings in which specialization is not considered necessary. Thus, many general ratings will consist of general rates in all pay grades.

The service rating reflects qualifications in some of the specific aspects of an occupational field and provides specialization where it is considered desirable. A service rate is the pay grade level within a service rating. Service ratings may exist through pay grade E-4, or through any other pay grade, including E-7, depending on the needs of the Navy.

The emergency rating reflects qualifications in a civilian skill not identified in the peacetime Navy, but required to be identified in wartime. An emergency rate is the pay grade level within an emergency rating.

The new rating structure for the I. C. Electrician, however, consists of the general rating only and does not include the service ratings. I. C. Electricians maintain and repair interior communication (IC) systems, gyrocompass systems, amplified and unamplified voice systems, alarm and warning systems, related equipment, and stand IC and gyrocompass watches.

QUALIFICATIONS FOR ADVANCEMENT

I. C. Electricians perform both military and professional duties. The military requirements and the professional qualifications for all the ratings in the Navy are listed in the Quals Manual. The Quals Manual is periodically revised to reflect organizational and procedural changes in the Navy that affect the rating structure, and to incorporate additional skills and techniques required by the development and installation of new equipment.

MILITARY REQUIREMENTS

The military requirements for I. C. Electrician are the same as those for other petty officers irrespective of the professional ratings. This training course primarily concerns the professional duties of I. C. Electricians and

does not attempt any detailed consideration of the military duties. The military requirements are discussed in *Basic Military Requirements*, NavPers 10054, and *Military Requirements for Petty Officers 3 and 2*, NavPers 10056.

PROFESSIONAL QUALIFICATIONS

The professional (technical) duties performed by I. C. Electricians include a variety of tasks that require many specialized skills and techniques necessary to perform properly the occupational duties of their rate within the rating structure.

The professional qualifications for I. C. Electricians are reprinted in appendix II. They have been used as a guide in preparing this training course and will be used by the U. S. Naval Examining Center in preparing the servicewide competitive examinations. It is important that personnel preparing for any examination refer to the latest revision of the Quals Manual for changes subsequent to the publication of this training course.

RECORD OF PRACTICAL FACTORS

The Record of Practical Factors, NavPers 760 (IC) is a standard checkoff list of all the practical factors required to be demonstrated in each rate as a prerequisite for advancement. When an I. C. Electrician demonstrates his proficiency in each practical factor listed on the form, the division officer or supervising officer initials and enters the date of completion in the appropriate column provided on the form. The leading chief is frequently given the job of maintaining the record of practical factors.

Each division maintains a Record of Practical Factors for each enlisted man in pay grades E-3 through E-6. When an enlisted man is transferred, the form is signed by the division officer, correspondence (left) side of the Enlisted Service Record and forwarded to the man's new duty station. In this way, his record is kept up to date and used on a continuing basis as he progresses in his rating.

Space is allowed on the Record of Practical Factors form for entering additional factors as they are published in changes to the Quals Manual.

REFERENCE MATERIAL

The I. C. Electrician 3 in preparing for advancement in rating must study certain publications in addition to this training course. The Reading List in the front of this book is especially useful as supplementary study material. The references listed under the headings, Navy Training Courses and other publications, are of particular importance because questions on the examination for advancement are based on material contained in these courses and publications as well as on material in this training course.

The reference contained in the Reading List are taken from *Training Publications for Advancement in Rating*, NavPers 10052, which is an annual bibliography published by the Bureau of Naval Personnel. This bibliography lists the current Navy Training Courses and other publications that have been prepared for the use of all enlisted personnel concerned with advancement in rating examinations. It is used by the Naval Examining Center in preparing military and professional examinations for advancement in rating and also by personnel preparing to take these competitive examinations.

In addition to the Navy training courses contained in the Reading List, *Mathematics*, Vol I, NavPers 10069-B, should be included as supplementary study material. This text will help you to acquire the necessary knowledge of shop mathematics.

Navy training courses can be obtained by application to your Information and Education Officer. He can help you to acquire other publications that may not be readily available.

LEADERSHIP

To satisfy military requirements for advancement in rating, it is necessary to study *Military Requirements for Petty Officer 3 and 2*. This training manual contains a chapter entitled, "Military Command and Leadership" in which the essentials of good leadership are covered.

Many books have been written on the subject of leadership and many traits have been listed for the success of a leader. But whether a petty officer is a successful leader or not will be decided, not by compiled lists of desirable traits, but for the most part by the success with which he stimulates others to learn and to perform.

His responsibilities are more than just giving orders and directing work. He has the

added responsibility of instructing those working under him. As a petty officer, the IC2 acts as a link in the chain of command between the division officer and the men who work for him.

Self-confidence is very important to leadership, but it must be supported by enthusiasm and knowledge. For example, an IC2 in supervising his men in the repair of equipment should not only know the necessary procedures thoroughly, but he should be ready to help do the job if necessary. The men respect a petty officer who has demonstrated his leadership and his ability in his field.

A cooperative attitude also is an important requirement of good leadership. An unreasonable or overbearing attitude on the part of a petty officer not only has an adverse effect on the morale of the men, but on their work as well.

HOW TO STUDY

The general methods of study are the same for everyone, but the real art entails discovery of the methods that are most advantageous for the individual. It is always best to study about a particular equipment while working on it. With a piece of equipment available, study the technical manual and relate the physical location and size of the component with it. On the job, learn by doing.

PLAN OF STUDY

When studying theory or operational material, it is very important to set up some plan of study. Study is a habit. It is best done under conditions and surroundings that will not distract the student. It is important that learning be done in an orderly fashion so that the acquired bits of knowledge will serve as stepping stones in the process of learning. Read and study the material at hand with as much concentration as possible.

RULES OF STUDY

Some basic rules for studying are:

1. Choose a comfortable, quiet, and well-lighted location. Read with pencil and paper handy for recording notes.
2. Decide upon a portion of a chapter and the number of pages to be studied.
3. Read quickly in order to get the main point of the subject.
4. Reread carefully.
5. When the material has been reread, put the book aside.
6. List the main points.
7. With the book open, check the main points.
8. Reread the material more slowly. Try to remember the details and connection of each part.
9. Write a detailed summary, using the book only if necessary.
10. When the details of the material have been thoroughly digested, turn to the end of the chapter and answer as many questions as possible without referring to the text.
11. Check the answers and make corrections.

This general method is of great benefit to those who find it difficult to learn and retain what they have read. Remember that electricity cannot be learned in a hurry. A consistent application of effort, however, brings a man to his goal sooner than he thinks.

SCOPE OF IC2 TRAINING COURSE

This text is written to cover the knowledge factors and also to cover the practical factors in the I.C. Electrician Rating.

Chapters 2 through 15 deal with engineering material, elementary physics, sound systems, motion picture systems, dial telephone systems, closed circuit TV, ship's control and metering systems, magnesyn and gyrocompasses, and optical landing systems.

I.C. ELECTRICIAN BILLETS

The I.C. Electrician may be assigned to almost any type of ship in the Navy and to various shore billets. The kind of work will depend upon the nature of the assignment. As a rule, the IC2 will be assigned specialized duties on large ships and a wider variety of jobs on small ships.

For example, on a small ship the duties of an I.C. Electrician may include the maintenance and repair of lighting and power circuits, whereas, on a large ship, a repair ship, or a tender, the IC2 may be assigned to more specialized work. He might be assigned to the gyrocompass, the telephone, or some shop specializing in one particular type of IC work.

QUIZ

1. Name the manual published by the Bureau of Naval Personnel that lists the military requirements and professional qualifications for all Navy ratings.
2. Why is the Quals Manual periodically revised?
3. Why should personnel preparing for an examination refer to the latest revision of the Quals Manual?
4. Name the three types of ratings that comprise the 1957 rating structure.
5. To what rating does the I. C. Electrician belong?
6. What are the two primary divisions of the qualifications for advancement in rating?
7. How are proficiencies and knowledges of each of these two classifications tested?
8. Name the NavPers form that contains the practical factors for the military and professional requirements for each general rating.
9. How is the form used that is referred to in question 8?
10. Name the pay grades through which a record of the practical factors are maintained for each enlisted man.
11. What is the purpose of the Reading List in the front of this book?

CHAPTER 2

ENGINEERING MATERIAL

INTRODUCTION

An IC2 on an auxiliary or a small combat ship may be required to supervise personnel assigned to a gyro shop, telephone shop, or an IC room. On a larger ship the IC2 may be required to supervise the men responsible for the maintenance and repair of a circuit or several circuits. At a shore station, he may be responsible for various types of shops.

In order to supervise a shop or gang efficiently, the IC2 must know how to obtain, care for, and account for materials and supplies. The responsibility for maintaining adequate stocks of repair materials and repair parts belongs to both repair and supply personnel. The duties of the supply officer are to procure, receive, stow, issue, and account for most types of stores required for the support of the ship.

This chapter therefore will discuss those phases of supply that are concerned with engineering material.

TYPES OF MATERIAL

Material is the general term used in the Navy to designate supplies, repair parts, and equipment. The principal types of material are (1) consumable supplies, (2) equipage, (3) end items, (4) support equipment, (5) repair parts, (6) components, (7) common items, and (8) ship's machinery.

CONSUMABLE SUPPLIES

Consumable supplies is the general term used to designate operating and maintenance material consumed in use. The term does not include repair parts for equipment but does include such general stores material (GSM) as sheet gasket material, packing, and common sizes of nuts, bolts, and washers. It also includes ship's stores, subsistence, and clothing and small stores.

In general, consumable supplies are subject to rapid wear, or frequent replacement or replenishment, and are usually inexpensive.

EQUIPAGE

Equipage is the general term used AFLOAT to designate material of a nonconsumable nature. The term includes material that is usually of a greater value and more importance than consumable supplies, but does not include material consumed or appreciably altered in use. Equipment is the general term used ASHORE to designate the same type of nonconsumable material as equipage. In actual practice the term equipment is also used afloat.

END ITEM

An end item is a final combination of material that is ready for its intended use. It is an equipment or one of its subdivisions.

SUPPORT EQUIPMENT

Support equipment is the general term used to designate test equipment, ground support equipment, jigs, fixtures, and handtools. This material is required for the maintenance, assembly, disassembly, overhaul, repair, test, and check of the end item.

REPAIR PART

Repair part is an integral manufactured and replaceable part (or assembly) of a piece of machinery or equipment. The part is furnished normally for replacing a part worn or damaged in service.

COMPONENT

Component, also known to the Navy as a major unit, is a group of parts which, as an assembly, performs a definite function necessary

to the operation of the entire equipment. A compressor in a water cooler is an example of a component.

COMMON ITEM

A common item is of standard design, application, and specification and is normally procurable from several manufacturers or suppliers.

SHIP'S MACHINERY

Ship's machinery is defined as mechanically and electrically operated equipment installed in a ship or small boat. The machinery section of the ship's allowance lists contains a description of a majority of essential ship's machinery.

FEDERAL SUPPLY CLASSIFICATION SYSTEM

The Navy and other agencies of the Federal Government employ a standardized system of classification and identification for materials. The same identification data is assigned to identical stock so that all personnel concerned will use the same name, description, and stock number when referring to the same item.

Identification data such as stock numbers are just as important to the Navy as catalog numbers are to a large mail-order house. They both serve the purpose of filling orders for material accurately and promptly.

STOCK GROUPS AND CLASSES

The Federal Supply Classification (FSC) system has been adopted by the Defense Department for use in classifying items of supply identified in the Federal catalog system. The FSC has a potential of 99 groups. Each group is subdivided into as many classes as needed. At present the FSC consists of 89 groups, which are subdivided into approximately 540 classes.

The FSC groups and their titles are shown in the *Federal Supply Classification Handbook*, H2-3, Part 3, Alphabetic Index. The titles indicate the general nature of the material contained in each group (numbers omitted are unassigned). This publication also shows the class within each group for most common materials.

The first pages of each group in the Navy Stock Lists show the division (breakdown) of the group into FSC Classes. Each class covers a particular area of commodities in accordance with their physical or performance characteristics, or based on the fact that the items in the class are usually requisitioned or issued together. For example, the breakdown of group 31, which is bearings, into FSC classes is:

FSC Class	Title
3110	Bearings, antifriction, unmounted
3120	Bearings, plain, unmounted
3130	Bearings, mounted

FEDERAL STOCK NUMBERS

A Federal stock number consists of 11 digits (usually Arabic numbers) arranged in groups of 4, 3, and 4 separated by hyphens. The first four digits are the Federal Supply Classification (FSC) code number, the first two of which indicate the group and the second two indicate the class. The last seven digits are the Federal Item Identification Number (FIIN). The FIIN identifies a specific item within a group and class. For example, the breakdown of the FSN for 30-watt, fixed, wire-wound resistors is:

FSC Code Number 59 05 - 195-2430

Group ← 59

Class ← 05

Federal Item Identification Number ← 195-2430

Under the Federal Supply Classification System, almost all material now used by the Navy is assigned a Federal stock number (FSN), which is the same for all Government agencies. When given a correct stock number, supply personnel can locate detailed information concerning any item of standard stock.

SUPPLY MANAGEMENT CODES

A Federal stock number, when used within the Navy supply system, is preceded by a cognizance symbol consisting of a capital letter. Cognizance symbols identify the Navy bureau,

office, or supply demand control point (SDCP) that exercises supply management, or cognizance, over the material. For example, a cognizance symbol arranged with a FSN is

N 5905-195-2430

Cognizance symbol

The cognizance symbol N denotes that the item identified by the FSN is controlled by the Electronics Supply Office (ESO). A complete listing of cognizance symbols is contained in volume VIII of the *Bureau of Supplies and Accounts Manual.*

ALLOWANCE LISTS

The ship's allowance lists provide a complete list of equipage and consumable supplies, in addition to installed machinery, to be placed on board when the ship is commissioned. Each list is intended to include all equipment essential to the efficient operation and maintenance of the ship.

Allowance lists specify the amounts of onboard equipage and repair parts that a ship is required to carry. Ships are required to carry a full allowance of such material and are not permitted to exceed that allowance without bureau approval. In the case of consumable supplies, allowance lists provide a guide to the range and quantities of material that will be required to operate the ship. Allowance lists are used in the preparation of custody and stock records, to prepare requisitions for replacement material, to indicate proper identification of technical repair parts aboard, and to give information with respect to supplying activities.

At the present time, many ships and surface craft still have Revised Individual Allowance Lists (RIAL) for the listing of hull, mechanical, and electrical material (fig. 2-1). Detailed guides for the preparation of these Revised Individual Allowance Lists are contained in the Bureau of Ships Revised Master Allowance List and supplemental directives. This publication also establishes the various kinds of allowance lists to be prepared, and defines the terms associated with their preparation and use.

A new type of allowance list is under development and will, in the near future, supersede the Revised Individual Allowance List (RIAL). The list is known either as Shipboard Allowance List (SAL) or as a Coordinated Shipboard Allowance (COSAL), depending on the coverage included. SALs cover hull, machinery, and electrical material only, whereas COSALs include electronic and ordnance material. The SAL and COSAL formats are identical and transition from SAL to COSAL can be easily accomplished.

SHIPBOARD ALLOWANCE LIST

If the ship has not yet received its Coordinated Shipboard Allowance List (COSAL), it is probably operating under the Shipboard Allowance List (SAL) for the hull, machinery, and electrical material requirements. In this case, refer to the Bureau of Ordnance Allowance Lists and the Bureau of Ships Allowance Lists, respectively, for the ordnance and electronic material requirements. When the ordnance and electronics sections are developed, they will be combined with the hull, machinery, and electrical sections, making the SAL a COSAL.

As previously stated, the formats used with the SAL are identical to those used with the COSAL. The only basic difference is in the stock number sequence list (part III). In the SAL, only repair parts supporting hull, machinery, and electrical components are included, whereas in the COSAL, repair parts for the support of all shipboard equipments are listed.

Bureau of Ships Allowance Lists

The Bureau of Ships allowance lists include (1) revised master allowance list, (2) type allowance lists, (3) revised individual allowance lists, and (4) electronics allowance lists.

The Revised Master Allowance List includes the proper description and nomenclature of specific types of material under the cognizance of the Bureau of Ships and approved for installation on, or placing aboard, all ships of the fleet.

The Type Allowance List covers the equipment installed in certain ships of a type or class.

The Revised Individual Allowance List is a specific and final allowance for a ship unless the ship has a COSAL, which supersedes the individual allowance list.

The Electronics Allowance List consists of (1) basic hull electronics allowances, (2) ship

BUREAU OF SHIPS ALLOWANCE LIST

BOOK FOR U. S. S.

TYPE LIST FOR

GROUP NAME MOORING MACHINERY

PART I

GROUP NO. S26

PAGE 2

TYPE PAGE

NAME AND DESCRIPTION OF REPAIR PART	ALLOW. DESIG.	STANDARD NAVY STOCK NUMBER	BUSHIPS PLAN NUMBER	PC. NO.	WGT.	UNIT OF ISSUE	ALLOWANCE
REPAIR PARTS - ANCHOR WINDLASS							
COMP. I.D. 63001-012							
Bearing Assy. - Crank Pin		H69-AEF-50397				Ea.	1
Consisting of:							
2 - Bearing - Crank Pin Half		DDD12P-C					
2 - Bearing - Crank Pin Half		DDD13P-C					
Bushing - Connecting Rod		H69-AEF-50388				Ea.	2
Bushing - Crank Pin		H69-AEF-50376				Ea.	2
Bushing - Crank Shft. Clutch Pnn.		H69-AEF-50360				Ea.	1
Bushing - Crank Shft. Slv. Pnn.		H69-AEF-50361				Ea.	2
Bushing - Cross Head		H69-AEF-50391				Ea.	4
Bushing - Eccentric Rod		H69-AEF-50340				Ea.	2
Bushing - Gypsy Shft. Pinion		H69-AEF-50353				Ea.	1
Bushing - Mn. Vl. Stem Stfg. Box		H69-AEF-50345				Ea.	2
Bushing - Pstn. Rod Stfg. Box		H69-AEF-50393				Ea.	2
Bushing - Rev. Valve Stfg. Box		H69-AEF-50380				Ea.	1
Bushing - Wildcat Inboard		H69-AEF-50374				Ea.	2
Bushing - Wildcat Outboard		H69-AEF-50373				Ea.	2
Clutch - Crankshaft		H69-AEF-50368					(A)
Clutch - Gypsy Shaft		H69-AEF-50357					(A)
Eccentric Assembly		H69-AEF-50398				Ea.	2
Consisting of:							
2 - Eccentric - Half		MD2-389S-B					
2 - Eccentric - Half		MD2-390S-B					
Gear - Crankshaft		H69-AEF-50369					(A)
Gear - Gypsy Shaft		H69-AEF-50358					(A)
Gear - Main		H69-AEF-50375					(A)
Liner - Crank Pin Bearing		H69-AEF-50379				Ea.	4
Liner - Eccentric Strap		H69-AEF-50328				Ea.	4
Liner - Main Valve		H69-AEF-50309				Ea.	2
Liner - Brake Band		H69-AEF-50407				Ea.	2
Note: (A) Not to be carried on board							

ISSUED 9-1-50

REVISED

For any repair parts required but not listed above, refer to REQUISITIONING GUIDE Navships 4050

ACTIVITY	PREPARED	TYPED	PROOFED	APPROVED
NAVSHIPYD SANFRAN	F.G.	MB		

REPAIR PARTS NAVSHIPS 4115 (REV. 1-49)

7.1

Figure 2-1.—Bureau of Ships Revised Individual Allowance List (RIAL).

electronic test equipment allowances, (3) fitting out allowances, (4) electronic repair parts allowances, and (5) supplemental allowances.

The Basic Hull Electronic Allowance is the official Bureau of Ships Allowance of electronic equipment for an individual ship.

The Ship Electronic Test Equipment Allowance is the material listed in the S69 allowance group. This material is in two parts, S69-1 for the electronic test equipment, and S69-2 for the electrical test equipment.

The Fitting Out Allowances are allowances in groups S67, S69-1, and S69-2 for which no installation work is involved. These allowances include portable equipment, test equipment, tools, maintenance parts, and tubes. Detailed instructions concerning allowances for fitting out items are listed in the *Bureau of Ships Fitting Out Manual*, NavShips 250-696.

The Electronic Repair Parts Allowance List (ERPAL) is a listing of the electronic equipment on board and the allowance of repair parts required to support that equipment. The ERPAL is designed to provide for consolidated storage and centralized stock record keeping. This list is prepared by the Electronic Supply Office (ESO). The Supplemental Allowance List is an additional listing in the same form as the ERPAL which covers additional installed equipment not listed in the basic ERPAL.

COORDINATED SHIPBOARD ALLOWANCE LIST

The Coordinated Shipboard Allowance List (COSAL) serves as a technical document to describe and establish mandatory quantities of onboard equipments, components, equipage, and directly supporting repair parts. The list also serves as a supply document to be the basis of shipboard inventory management.

The COSAL is prepared in segments, by category of material, in a simplified and uniform format. All requirements for a given cognizance symbol of material will appear in only one segment of the list. For example, all cognizance symbol N requirements will appear in only the electronics supply office segment, although the requirement may originate from an equipment in the Ordnance Supply Office segment or in the Ships Parts Control Center segment. This process improves the endurance capability of a ship and reduces the quantities of repair parts.

Each material category segment of the COSAL is prepared by the cognizance Supply Demand Control Point (SDCP) and assembled in a separate binder. The COSAL contains (1) introduction, (2) equipment index (part I), (3) allowance parts list (part II), and (4) stock number sequence list (part III).

The INTRODUCTION contains general instructions for the use and maintenance of the COSAL, and specific instructions and information peculiar to the material category segment covered.

The EQUIPMENT INDEX (part I) specifies the kind and quantities of equipments, components, and equipage allowed the ship to perform its mission. Items are listed by name or function, or both. Part I is the basis for the repair part support provided in the COSAL stock number sequence list (part III).

The ALLOWANCE PARTS LIST (part II) consists of a set of Allowance Parts List (APL). An allowance parts list is provided for each equipment or equipage category listed in part I.

Equipment Allowance Parts Lists contain a technical description of the equipment and list each repair part in the equipment regardless of material cognizance. Storeroom quantities of onboard repair parts listed in the APL are consolidated by stock number and cognizance in part III.

The STOCK NUMBER SEQUENCE LIST (part III) is the authorized allowance list of repair parts and materials required to be onboard the ship to support the equipments listed in part I of the COSAL. It is compiled by cognizance symbol and stock number from the equipment allowance parts lists. Each line item specifies the stock number of the repair part, the allowed quantity, and the equipment supported.

For mechanical and electrical equipment, the Stock Number Sequence List (SNSL) consists of sections A and B. Section A covers onboard repair parts to be placed in the storeroom, whereas section B covers items to be placed in operating spaces.

Assume that a casualty occurs to an onboard equipment and it is desired to determine the repair parts available for immediate repairs. If the name of the equipment and nameplate data are known, refer to section A of the equipment index (part I), which is in alphabetical sequence by name. When the correct item is found in the index, obtain the (1) identification number

(application code), and (2) quantity installed aboard the ship.

If the nameplate is missing but the service application is known, refer to section B of the equipment index (part I), which is in alphabetical sequence by service application. When the service application is found, obtain the same information that was available in section A.

Consult the allowance parts list (part II) where all APLs that are applied to the ship are filed in numerical sequence. In the APL: find the complete equipment characteristics data and a breakdown of repair parts. Select the required part(s) by reference to either its name, description, or number.

If a quantity appears in the allowance table on the APL, it indicates that the part is considered to be an onboard item. If no quantity appears, it indicates that the part is not considered an onboard item for that APL only. Therefore, before ordering from the Navy supply system, refer to the stock number sequence list (part III) to be certain that the part is not allowed as an onboard repair part for some other equipment installed in the ship.

After the stock number of the desired onboard repair part is obtained, refer to the stock number sequence list (part III) to locate the final authorized onboard allowance quantity. The SNSL also lists all other equipments that use the same part.

CATEGORIES OF MATERIAL

The principal categories of material used by the engineering department aboard ship comprise (1) Bureau of Ships repair parts, (2) general stores material, and (3) Bureau of Ships material not carried in stock.

BUREAU OF SHIPS REPAIR PARTS

Bureau of Ships repair parts are usually parts, fittings, and accessories that are used to repair equipment and to fill allowances. To properly control these parts, the Bureau of Ships, in conjunction with the Bureau of Supplies and Accounts, has directed certain supply demand control points to act as agents in the inventory control of repair parts. Instructions concerning the handling of Bureau of Ships repair parts are promulgated by these supply demand control points. The categories of Bureau of Ships repair parts are (1) ship's assemblies and repair parts, cognizance symbol H, and (2) submarine assemblies and repair parts, cognizance symbol P.

Ship's Assemblies and Repair Parts, Cognizance Symbol H

Cognizance symbol H material includes shipboard electrical material and ship's assemblies, repair parts and special tools required to support equipments aboard surface ships, and designated submarine equipments, including some repair parts used on submarines.

Examples of ship's assemblies and repair parts are:

1. Internal combustion engines and accessories built to shipboard specifications.
2. Equipment essential to propulsion, steering and ship control such as turbines, generators, motor-generator sets, reduction gears, boilers, pumps, compressors, hull fittings, propellers and shafting, electric motors, blowers, heat exchangers, distilling plants, steering apparatus and devices, electrical control equipment, and gyrocompass equipment.

Submarine Assemblies and Repair Parts, Cognizance Symbol P

Cognizance symbol P material includes submarine and nuclear reactor assemblies, and repair parts and special tools required for the support of the following equipment used primarily or solely on submarines.

1. Equipments for propulsion, power generation and distribution, steering, and diving.
2. Hull fittings and access equipment.

GENERAL STORES MATERIAL

Material in general use is known as general stores material. This material is under the inventory control of the Bureau of Supplies and Accounts, but many items are under the technical control of the Bureau of Ships.

General stores material includes items of a general nature or application that may be used in one or more of the several basic programs of the Navy and that conform to Federal, military, or approved commercial applications.

These items are classified in one or more of the following categories:

1. Administrative and maintenance type.
2. Industrial and shop type.
3. Construction and building materials and supplies.
4. Hardware, electrical items, and repair parts not belonging to specific categories of equipment or components thereof, and certain consumable supplies.
5. Equipments and accessories (including repair parts).
6. Metallic and nonmetallic materials in fabricated or semifabricated form.

BUREAU OF SHIPS MATERIAL NOT CARRIED IN STOCK

The material previously described is normally carried in stock. However, some items of Bureau of Ships material such as battens, gratings, or steam castings are not stocked. These items are fabricated as required by the ship's force or repair activities, or are obtained under contracts either prepared or approved by the Bureau of Ships. In special cases, a naval shipyard may be required to fabricate certain items not carried in stock.

REQUESTS FOR MATERIAL

The supply officer is responsible for the procurement of all equipment and supplies needed by the ship, except for medical stores, ammunition, Marine Corps stores, and those materials automatically furnished to ships without action by the ship. The supply officer procures replenishment material for supply department stocks, and also procures supplies at the request of heads of departments when such requests are within the limits of the ship's allowance.

The term, ISSUES, refers to expenditures of material from the custody of the supply department to shipboard use. Issues are made on Request For Issue or Turn-In (DD Form 1150) illustrated in figure 2-2.

Department heads have authority to request material for the operation of their departments. These requests must not exceed the departmental budget limitations, when established, unless authorized by the commanding officer. Issues will be made to individuals who are properly authorized by the respective department heads.

Request For Issue or Turn-In are prepared in triplicate by storeroom storekeepers. The authorized representative of the department must be prepared to properly identify the required items as to stock number and general description.

The storeroom storekeeper must record the correct stock number, unit of issue, and quantity of issues, in order to maintain accurate stock record cards. Material that is in critical supply will not be issued without prior approval of the supply officer or his assistant.

Issue documents must be initialed by the storekeeper making the issue and signed by the individual receiving the material. The second copy of the request document is furnished to the individual receiving the material.

EQUIPAGE

The engineer officer is responsible for initiating requests for equipage to replace unserviceable, lost, or missing items not requiring survey; to fill allowances; and to turn in material in excess of allowance. When equipage is required, the engineer officer will submit to the supply officer a completed Request For Issue or Turn-In (DD Form 1150).

In the case of replacement of surveyed material, the issue request will accompany the original survey request submitted by the department head. If equipage that does not require survey is to be replaced, the issue request will contain the statement "required to replace like items (no longer serviceable), (destroyed), or (missing). Survey not required."

ELECTRONIC EQUIPMENT AND MAINTENANCE REPAIR PARTS

The supply officer is responsible for the procurement of electronic equipment components on the ship's authorized allowances and maintenance repair parts for authorized onboard equipments.

The Bureau of Ships controls the procurement, distribution, and issue of major electronic equipment. Authority to issue equipment and components to fill allowances is delegated to electronics officers of naval shipyards or naval districts.

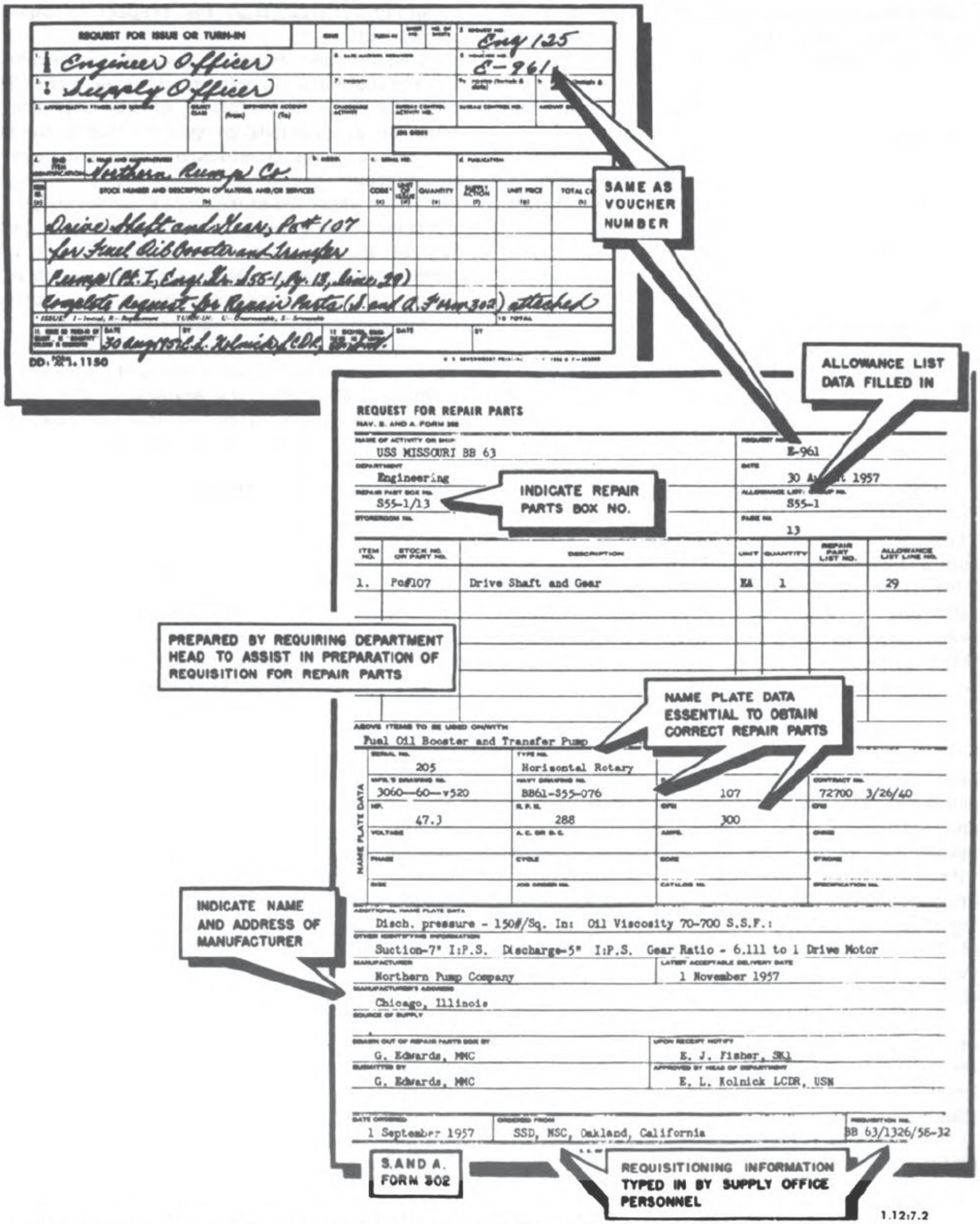


Figure 2-2.—Request For Issue or Turn-In (DD Form 1150) and Request For Repair Parts (SandA Form 302).

The engineer officer is responsible for the procurement of repair parts in his custody. He has the division concerned prepare a Request For Issue or Turn-In (DD Form 1150) and he forwards this request to the supply department when the repair part(s) is removed from the repair parts box or bin for installation in the parent equipment.

Requests for material are handled more quickly and efficiently if the stock numbers are known, therefore every effort should be made to locate the stock number before submitting a request for material. Stock numbers may be found in a variety of places such as: (1) on nameplates, (2) in manufacturers' technical manuals and catalogs, (3) on stock cards kept by the supply officer, (4) in Specifications For Ships, (5) in ships plans, (6) on blueprints, (7) in allowance lists, (8) machinery history, and (9) old repair records.

If the stock numbers for the required items are not available, the Request For Issue (DD Form 1150) must be accompanied by a Request For Repair Parts (SandA Form 302) complete with all essential nameplate data (fig. 2-2).

Many items listed in allowance lists and manufacturers' catalogs by part number, such as wire, tape, fuses, nuts, bolts, washers, screws, and so forth, are similar to common general store material. Before ordering these items as repair parts, check the Navy stock list of general stores to determine if a suitable general stores substitute can be found.

When such items of repair parts are identified as general stores material, enter the stock number opposite the item in the allowance list with the notation "Storeroom Stock." The replenishment of such material is procured by the supply officer in the same manner as other items of stores with appropriate stock records and established high and low limits based on issues.

MATERIAL CUSTODY AND STOWAGE

As previously stated, the supply officer is responsible for all supplies in store afloat, except ammunition, fuel, Marine Corps, and medical supplies. He shows evidence of this custody with properly maintained stock records. When it is necessary to stow materials in spaces not under the authority of the supply officer, he maintains custody receipts and records to show evidence of the responsibility of other department heads.

EQUIPAGE

Equipage aboard ship is in the custody of the head of the department responsible for the use of that equipment. The department head is responsible for ALL equipage in his custody and signs custody receipts for these articles. He may delegate the physical custody of material to subordinates in his department, but this delegation does not reduce his responsibility.

SHIP'S MACHINERY AND REPAIR PARTS

In order for the supply officer to exercise close control over the issue and replenishment of repair parts, he has custody of all stock in drawer and shelf stowage, and normally has custody of all machinery repair parts boxes. The supply officer has charge of the stock control of all items of machinery repair parts. If suitable space is not available for assignment to the supply officer for the stowage of repair parts boxes, the commanding officer will authorize the responsible department head to assume custody of repair parts boxes, stating the reason for this action. This authorization will be in writing, and a copy will be maintained on file in the supply office.

Major repair parts that are not boxed and cannot be cared for adequately in supply department storerooms because of their size may be kept in the custody of responsible department heads without special authorization from the commanding officer.

Stowage

Repair parts boxes are stowed in special storerooms when possible. On ships where it is impossible to stow repair parts boxes in storerooms, they are located near the machinery to which the repair parts pertain.

The IC electrician is often delegated the responsibility of stowing repair parts boxes assigned to the custody of E division. As custodian of repair parts, the IC2 should ensure that (1) stowage spaces are partitioned properly to prevent loose parts or boxes from sliding with the motion of the ship; (2) racks are constructed to facilitate the handling of the boxes;

(3) contents of the boxes are protected against undue motion; and (4) inventory can be taken easily and without disturbing the protective coating (wrapping) of the individual pieces.

Upon the issue of stock number sequence lists and the accomplishment of the necessary Shipalts, mechanical-electrical repair parts will be stowed in drawers and bins in designated storerooms.

Identification

Boxes in which sets or parts of sets of repair parts are stowed are numbered according to the group index number of the material, as shown on the allowance list. Repair parts boxes are further identified by the page number on which the repair parts are listed. For example, repair parts for the ship service generator might be listed S61/30. In this case, the generators are in group S61, and the repair parts are listed beginning on page 30. The additional boxes of repair parts for the generators may be numbered in the same manner and letters added in alphabetical sequence, as S61/30A, S61/30B, and so on. On the face of the box are listed the name, a brief description of the machinery concerned, and such other identifying information as is considered necessary.

Inside the box is posted a list of parts that are contained in the box. This list is required for initial fitting-out purposes but is not required to be updated or retained after the ship's stock records have been established. Individual repair parts are marked with the stock number, manufacturer's part number, or allowance list group, page, and line number.

STOCK RECORDS AND INVENTORY CONTROL

Inventory is the term that refers to material for which an individual stock record card is maintained on each item. To ensure that ships carry the proper amount of stock or material necessary to sustain operations for a maximum period of time, effective inventory control procedures must be maintained.

EQUIPAGE

The Equipage Stock Card and Custody Record (SandA Form 306 or 460) serves as a custody record and inventory control document for equipage (fig. 2-3). This form is maintained for equipage requiring custody signature by the engineering officer.

SHIP'S MACHINERY AND REPAIR PARTS

Stock records for boxed sets of repair parts consist of inserting a Stock Control Record—Ship's Repair Parts (SandA Form 489 or 489A) opposite each page of the Bureau of Ships allowance list on which repair parts appear (fig. 2-1). This stock control record (fig. 2-4) is designed for use with all Bureau of Ships allowance books. These insert sheets (SandA Form 489 or 489A) are designed for recording usage, replenishment, and locator data directly opposite the descriptive information appearing on the allowance list. Locator data include box, bin, and storeroom numbers.

As parts are issued, a record of each issue is maintained by the supply department on the insert sheet. Immediately after each part is issued for use, a replenishment requisition is prepared, and the requisition number is entered. As machinery repair parts are received, a notation is made on the insert form.

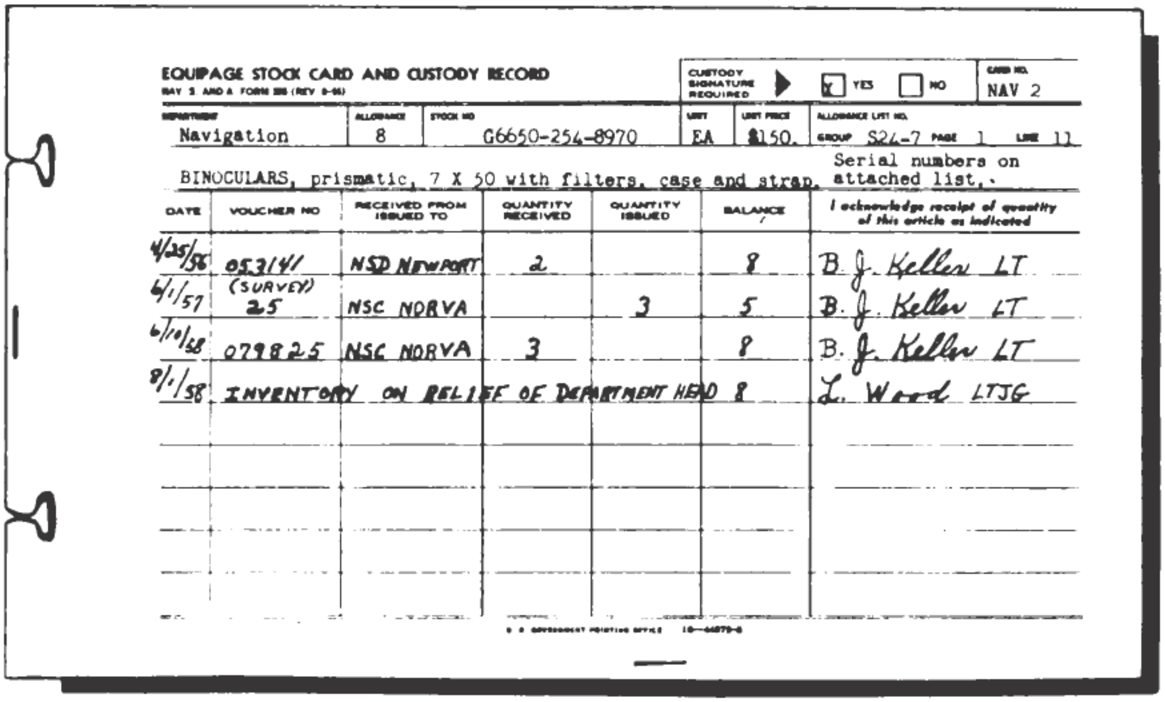
Stock records for drawer and bin stowed repair parts are maintained on a Repair Parts Stock Record (SandA Form 488) by the supply officer for each item of Bureau of Ships repair parts carried on board (fig. 2-5).

Inventory of mechanical-electrical repair parts is taken periodically as the commanding officer directs. However, each set of repair parts must be inventoried at least once during the fiscal year.

SURVEY OF MATERIAL

A survey is a determination of the disposition and the consequent expenditure from records of material that is deteriorated, lost, damaged, or otherwise rendered unavailable for its intended use under circumstances requiring examination of the cause of the loss. The general types of surveys are formal and informal.

A FORMAL SURVEY is made by either a commissioned officer or a board of three officers, one of whom and as many as practicable will be commissioned officers appointed by the commanding officer.


EQUIPAGE STOCK CARD AND CUSTODY RECORD

CUSTODY SIGNATURE REQUIRED [X] YES [ ] NO — CARD NO. NAV 2

DEPARTMENT	ALLOWANCE	STOCK NO	UNIT	UNIT PRICE	ALLOWANCE LIST NO.
Navigation	8	G6650-254-8970	EA	$150.	GROUP S24-7 PAGE 1 LINE 11

BINOCULARS, prismatic, 7 X 50 with filters, case and strap. Serial numbers on attached list.

DATE	VOUCHER NO	RECEIVED FROM / ISSUED TO	QUANTITY RECEIVED	QUANTITY ISSUED	BALANCE	I acknowledge receipt of quantity of this article as indicated
4/25/56	053141	NSD NEWPORT	2		8	B. J. Keller LT
6/1/57	(SURVEY) 25	NSC NORVA		3	5	B. J. Keller LT
6/10/58	079825	NSC NORVA	3		8	B. J. Keller LT
8/1/58	INVENTORY ON RELIEF OF DEPARTMENT HEAD				8	L. Wood LTJG

7.3

Figure 2-3.—Equipage Stock Card and Custody Record (SandA Form 306).

An INFORMAL SURVEY is made by the head of the department having custody of the material to be surveyed. An informal survey is used in all cases when a formal survey is not required or directed by the commanding officer.

SURVEY PROCEDURE

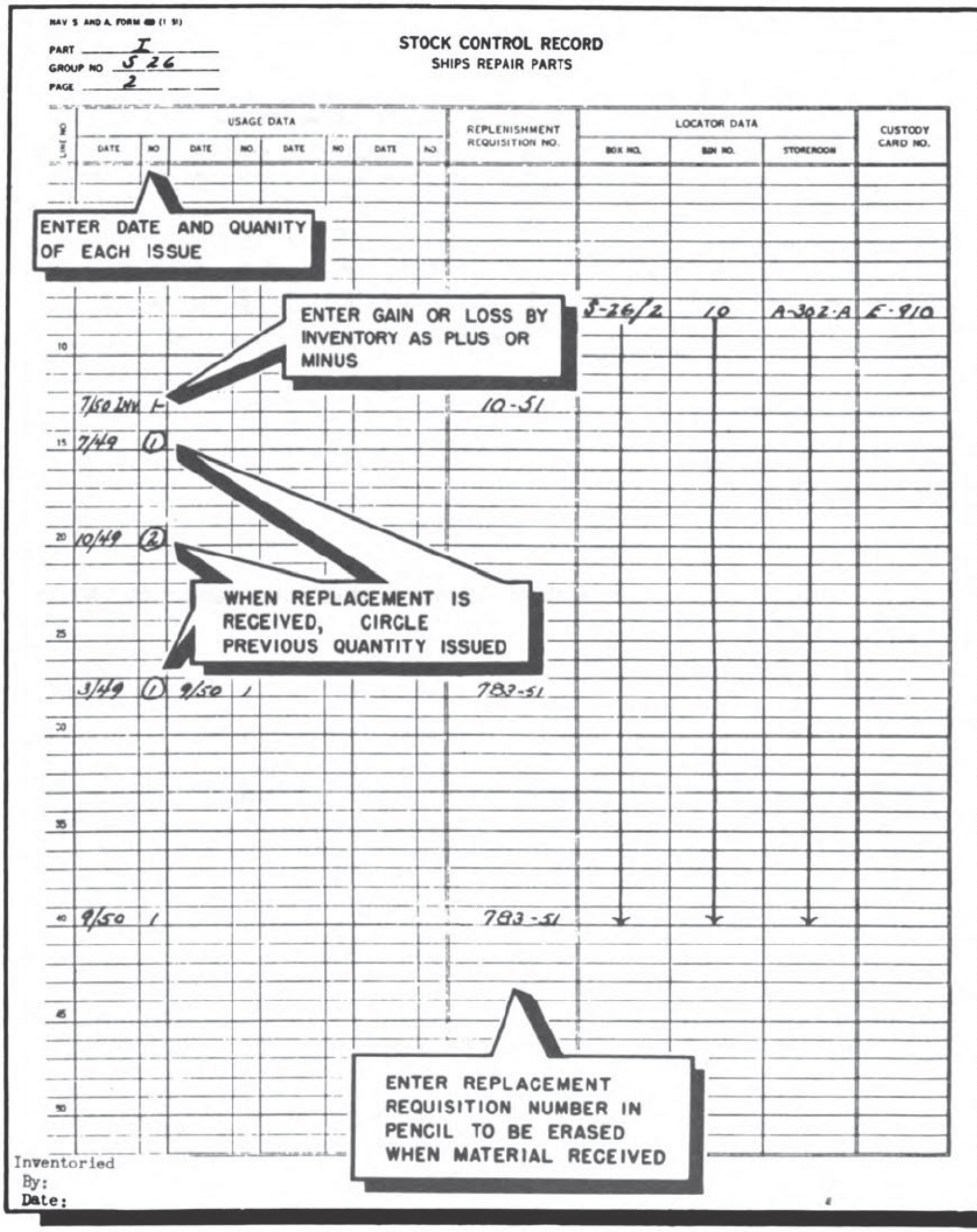
A survey procedure involves (1) request for survey, (2) action by commanding officer, (3) preparation of survey report, (4) action by reviewing officer, and (5) survey expenditure accounting.

Request for Survey

The survey request may be originated by any department, division, or section head, or by a designated subordinate. Normally, the survey request is originated in the department having custody of the material to be surveyed.

The initial survey request is made in rough on a Survey Request, Report, and Expenditure (SandA Form 154) illustrated in figure 2-6. Included on, or attached to, the initial survey request is a statement of the opinion of the originator concerning the (1) condition of the material; (2) cause of loss, damage, deterioration, or obsolescence of the material; (3) responsibility for the cause or condition, if such can be determined; and (4) recommended disposition of the material and the action to be taken.

The description of the material will be as complete as possible and will include serial numbers, if applicable, of the items involved. In addition, pertinent references to bureau manuals or other directives that specifically require formal survey or special disposition of surveyed material are made on the initial survey request. This initial survey request is not considered as the survey report, but is a guide to the commanding officer in determining the type of survey to be held and an aid to the surveying officer, board, or department head in the preparation of the survey report. The initial survey request is forwarded to the supply department for preparation of the smooth survey request.



7.4

Figure 2-4.—Stock Control Record (SandA Form 489).

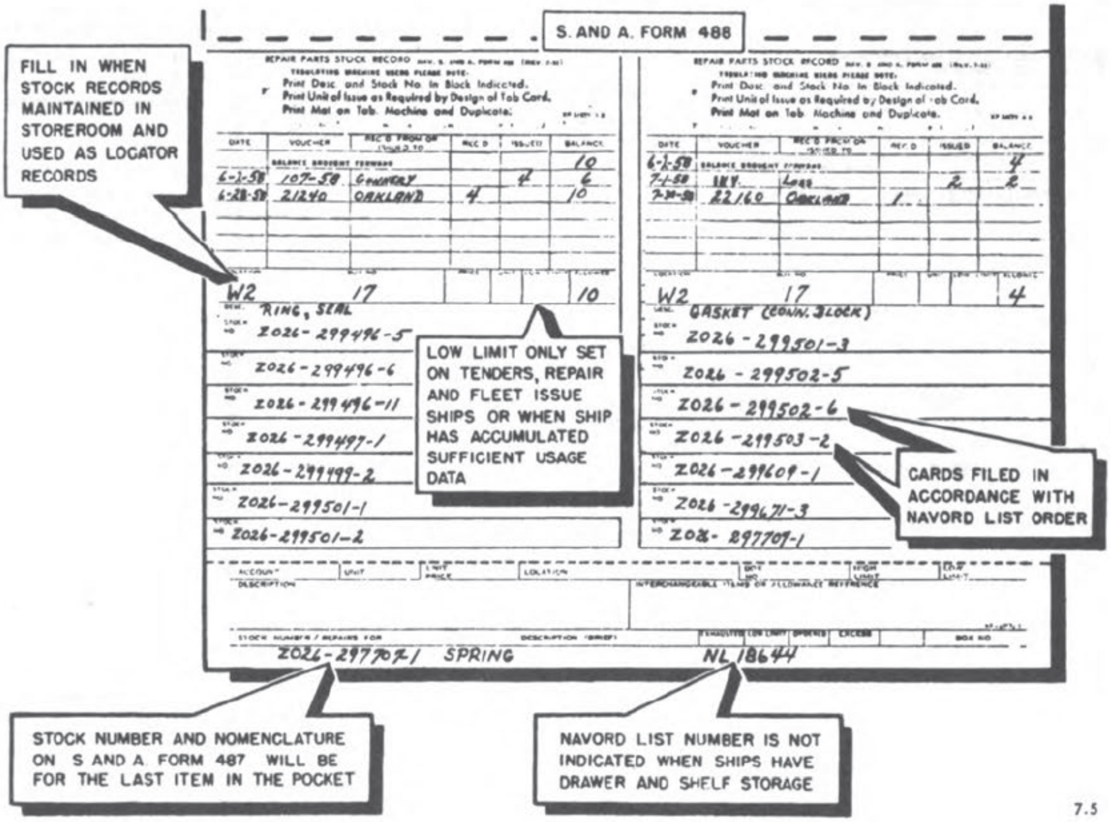


Figure 2-5.—Repair Parts Stock Record (SandA Form 488).

Action by Commanding Officer

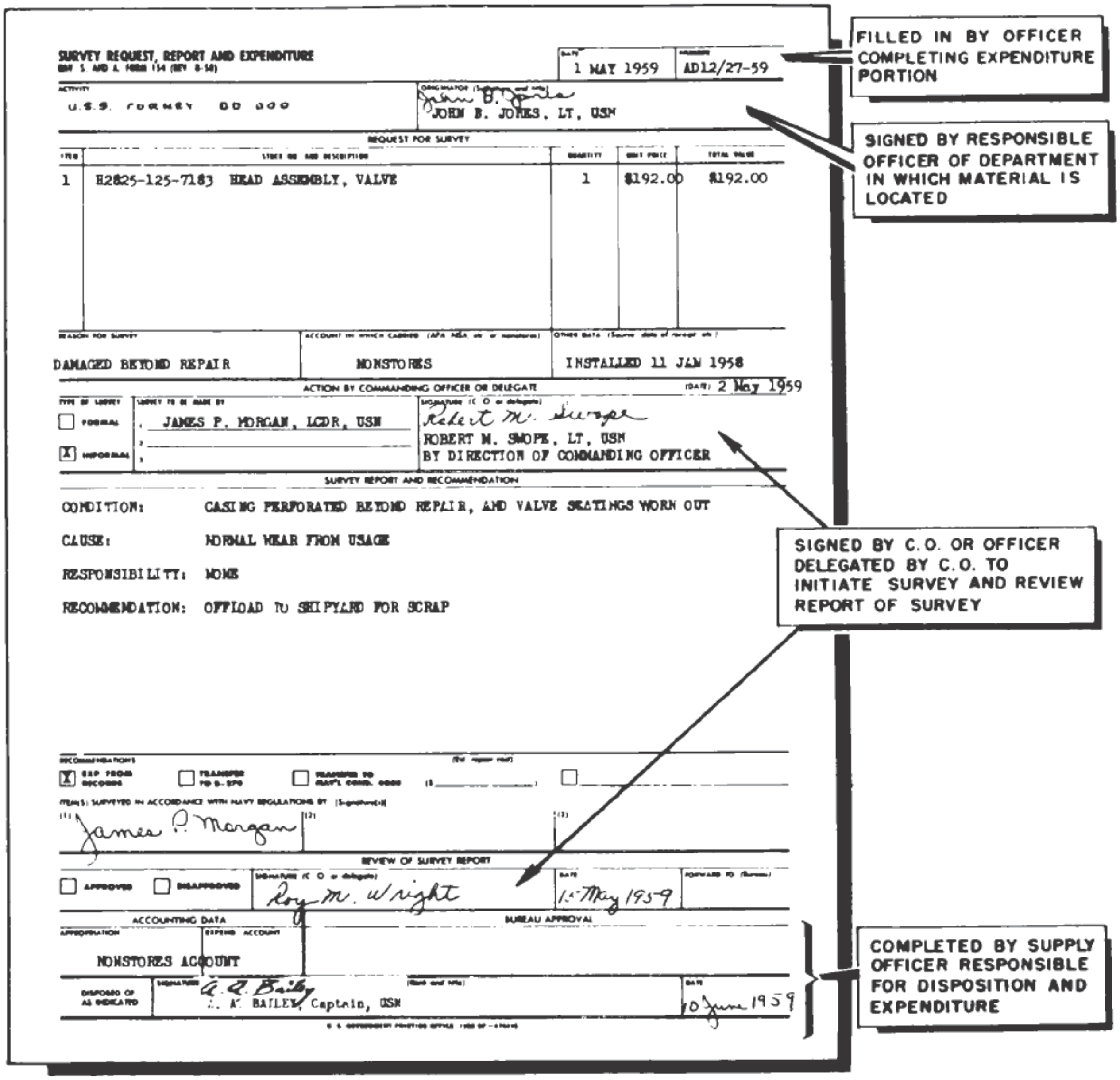
Upon receipt of the smooth survey request, the commanding officer or his representative determines whether a formal or an informal survey is appropriate. For formal surveys, the smooth survey request is forwarded to the surveying officer as designated by the commanding officer. For informal surveys the smooth survey request is forwarded to the head of the department having custody of the material to be surveyed.

The surveying officer, board, or department head will fix the cause and responsibility and prepare a survey report. When required, the services of qualified persons will be furnished to assist in the examination of material under survey or in the preparation of estimates for repairs.

After action by the surveying officer, board, or department head, the survey report is submitted for review to the commanding officer who takes whatever action he deems necessary.

REPORTING EQUIPMENT STATUS AND WORK ACCOMPLISHMENT

An I.C. Electrician 2 is required to maintain a number of records, checkoff lists, and reports at his assigned station. These records and reports are a very important part of his job. They provide data for keeping the ship's company advised concerning changes and alterations to equipment, surveying old equipment, informing boards of inspection and survey, keeping the Bureau of Ships informed as to the material status of the ship, and comparing the operational characteristics of each vessel with those of other vessels of the same type for recommended improvements. These records and reports comprise the Machinery Index, the Material History Record, and Maintenance Records.


SURVEY REQUEST, REPORT AND EXPENDITURE

Date: 1 MAY 1959 — Number: AD12/27-59

Activity: U.S.S. FORNEY DD 000

Originator: JOHN B. JONES, LT, USN

REQUEST FOR SURVEY

Item	Stock no. and description	Quantity	Unit price	Total value
1	H2825-125-7183 HEAD ASSEMBLY, VALVE	1	$192.00	$192.00

Reason for survey: DAMAGED BEYOND REPAIR — Account: NONSTORES — Other data: INSTALLED 11 JAN 1958

ACTION BY COMMANDING OFFICER OR DELEGATE — Date: 2 May 1959

Type of survey: ☐ FORMAL ☒ INFORMAL — Survey to be made by: JAMES P. MORGAN, LCDR, USN

Signature: Robert M. Swope — ROBERT M. SWOPE, LT, USN, BY DIRECTION OF COMMANDING OFFICER

SURVEY REPORT AND RECOMMENDATION

CONDITION: CASING PERFORATED BEYOND REPAIR, AND VALVE SEATINGS WORN OUT

CAUSE: NORMAL WEAR FROM USAGE

RESPONSIBILITY: NONE

RECOMMENDATION: OFFLOAD TO SHIPYARD FOR SCRAP

Recommendations: ☒ EXP FROM RECORDS

Item(s) surveyed in accordance with Navy Regulations by: James P. Morgan

REVIEW OF SURVEY REPORT

☐ APPROVED ☐ DISAPPROVED — Signature: Roy M. Wright — Date: 15 May 1959

ACCOUNTING DATA — BUREAU APPROVAL

NONSTORES ACCOUNT

DISPOSED OF AS INDICATED — Signature: A. A. Bailey — A. A. BAILEY, Captain, USN — Date: 10 June 1959

7.6

Figure 2-6.—Survey Request, Report, and Expenditure (SandA Form 154).

MACHINERY INDEX

The Machinery Index is a comprehensive listing of all machinery and equipment, exclusive of electronic equipment, installed in each vessel. The index for each item of equipment includes the material group number, complete nameplate data, the manufacturer's instruction book number, and its location in the ship. This information is required by the Bureau of Ships to provide adequate repair parts, battle damage components, and replacement equipment of the force afloat.

The ELECTRONIC INVENTORY serves the same purpose for electronic equipment as the machinery index serves for all other units.

MATERIAL HISTORY RECORD

A great deal of care is required to keep the Material History Record up to date and accurate. It consists of cards filed in loose leaf binders. These cards list all items of machinery by group numbers with descriptive data and the history of repairs and alterations for each item. Entries are made on the cards which describe repairs effected, derangements experienced, alterations, field changes, tests conducted, and other data necessary to provide a comprehensive history of the items concerned.

CURRENT SHIP'S MAINTENANCE PROJECT

The Current Ship's Maintenance Project (CSMP) provides a means of keeping a running record of all work that is planned in advance. The following three types of cards comprise the CSMP:

1. Repair Record, NavShips 529 (blue)
2. Alteration Record, NavShips 530 (pink)
3. Record of Field Changes, NavShips 537 (white)

As a repair is required or an alteration is authorized, an applicable card is filled in and placed in the Material History Binder adjacent to the proper history card.

The REPAIR RECORD CARD and the ALTERATION RECORD CARD, which are colored blue and pink respectively, provide a quick reference to current and pending work. When the item of work has been completed and the proper notation has been entered on the Material History Card, these cards are removed from the binder and placed in a "completed work" file.

The RECORD OF FIELD CHANGES CARD is used for each model or type of electronic equipment for which field changes are authorized. As field changes are authorized, the number, title, and authorization are entered on the card.

The remaining spaces provided on the card are filled in when the field change is completed. The RECORD OF FIELD CHANGES CARD is filed in the Material History Binder adjacent to the history card for the equipment to which the field changes apply.

MAINTENANCE RECORDS

An I.C. Electrician 2 keeps two types of maintenance records. One type of record is the official NavShip forms prepared by the Bureau of Ships, another is the type of ship's forms prepared by the engineering department. The number of these latter forms and the method of recording test, inspection, and maintenance data are prepared for a particular installation and class of vessel.

SHIP'S MEMORANDUM WORK REQUEST

It is important that the Ship's Memorandum Work Request be properly completed because it is not only used as an interim record but when work is completed it forms the basis for making entries in the Ship's Material History Record. These work requests are interdepartmental forms used by any department requiring work to be performed by another shipboard department. This memorandum ensures the proper routing of work requests between heads of departments. These work requests, or job orders, list the work to be done, and include an estimate of the man hours and material required to complete the job. Space is also provided for the shop that performs the work to list the material used, the man hours expended, date of completion, and the approximate cost. Similar forms are filled in when a ship requires work to be done by a ship yard or tender.

COMPASS RECORD BOOK

The COMPASS RECORD BOOK is a history of inspections, repairs and alterations to a gyrocompass. All routine inspections are listed in this book and signed by the person making the inspection. The Compass Record Book belongs with the gyrocompass and goes with it when the compass is removed.

QUIZ

1. What type of material is designated by the term consumable supplies?
2. What type of material is designated by the term equipage?
3. What type of material is designated by the term repair part?
4. Name the standardized system adopted by the Federal Government for the classification and identification of materials.
5. (a) How many digits comprise a Federal stock number, and (b) how are these digits arranged into groups?
6. Of the first four digits that comprise the FSC code number, what do the (a) first two digits, and (b) last two digits indicate?
7. (a) What are the last seven digits called in the Federal stock number, and (b) what do they identify?
8. When a capital letter precedes a Federal stock number, (a) what is it called, and (b) what does it identify?
9. What is the purpose of the ship's allowance list?
10. Name the two new types of allowance lists that will supersede the RIAL.
11. Name the material covered by each of these new allowance lists.
12. What transition occurs when the ordnance and electronics sections are developed and combined with the hull, machinery, and electrical sections?
13. Name the four parts that comprise the COSAL.
14. In what section of the equipment index (part I) of the COSAL is the (a) name, and (b) service application of a component listed respectively in alphabetical sequence?
15. What information must be obtained from the equipment index (part I) of the COSAL when the correct component or application is found?
16. What information is obtained by means of the component identification number from the Appliance Parts List (part II) of the COSAL?
17. After the stock number of the desired onboard repair part is obtained, what information must be obtained from the Stock Number Sequence List (part III) of the COSAL?
18. Name the three principal categories of material used by the engineering department aboard ship.
19. Name the two categories of Bureau of Ships repair parts.
20. What type of control is exercised by the Bureau of Supplies and Accounts and the Bureau of Ships, respectively, over many items of general stores material?
21. What is meant by the term issues?
22. Name the form the engineer officer uses to initiate requests for material.
23. When are requests for issue of repair parts prepared?
24. Name the form that must be filled in and accompany a Request For Issue or Turn-In (DD Form 1150) when the Navy stock numbers for the required items are not available.
25. Why should the Navy stock list of general stores be checked before ordering items in allowance lists, including gasket material, nuts, bolts, and washers?
26. What action is taken if any of the items listed in question 25 are identified as general stores material?
27. Who is responsible for the custody of equipage aboard ship?
28. Who is normally responsible for the custody of ship's machinery repair parts boxes?
29. Where are machinery repair parts boxes stowed when it is not possible to stow these boxes in special storerooms?
30. How are machinery repair parts boxes identified?
31. How are individual parts in the repair parts boxes identified?
32. What is meant by the term inventory?
33. Name the form used as a custody record and inventory control for equipage.
34. Name the form used as a stock control record for ship's repair parts.
35. Where are the forms referred to in question 34 filed?
36. What is the purpose of the forms referred to in questions 34 and 35?
37. How often are ship's repair parts inventoried?
38. Who makes a formal survey?
39. Who make an informal survey?

40. When is an informal survey made?
41. What form is used to make an initial survey request?
42. What is the disposition of the initial survey request after it has been made in rough on SandA Form 154?
43. What action does the commanding officer take upon receipt of the smooth survey request?
44. What action is taken by the surveying officer, board, or department head upon receipt of the smooth survey request from the commanding officer?
45. What action does the reviewing officer take upon receipt of the survey report from the surveying officer, board, or department head?

CHAPTER 3

PRINCIPLES AND ASPECTS OF SOUND AND SOUND SYSTEMS

Chapter 3 introduces the elementary physics of sound and wave motion. It includes the measurement of sound with examples of the decibel. Also, the overall aspects of a sound system are described.

PRINCIPLES OF SOUND

Sound is the result of vibrations in matter which are capable of being detected by the ear. These vibrations may be transmitted through gases, liquids, or solids, but cannot travel in a vacuum.

Sound travels through matter in the form of wave motions. These waves are called longitudinal waves because the particles of the medium vibrate back and forth longitudinally in the direction of propagation (fig. 3-1).

PROPAGATION OF SOUND

When the tine of the tuning fork (fig. 3-1) moves in an outward direction, the air immediately in front of the tine is compressed so that its momentary pressure is raised above that at other points in the surrounding medium. Because air is elastic, this disturbance is transmitted progressively in an outward direction from the tine in the form of a compression wave.

When the tine returns and moves in an inward direction, the air in front of the tine is rarefied so that its momentary pressure is reduced below that at other points in the surrounding medium. This disturbance is similarly propagated in the form of a rarefaction (expansion) wave and follows the compression wave through the medium.

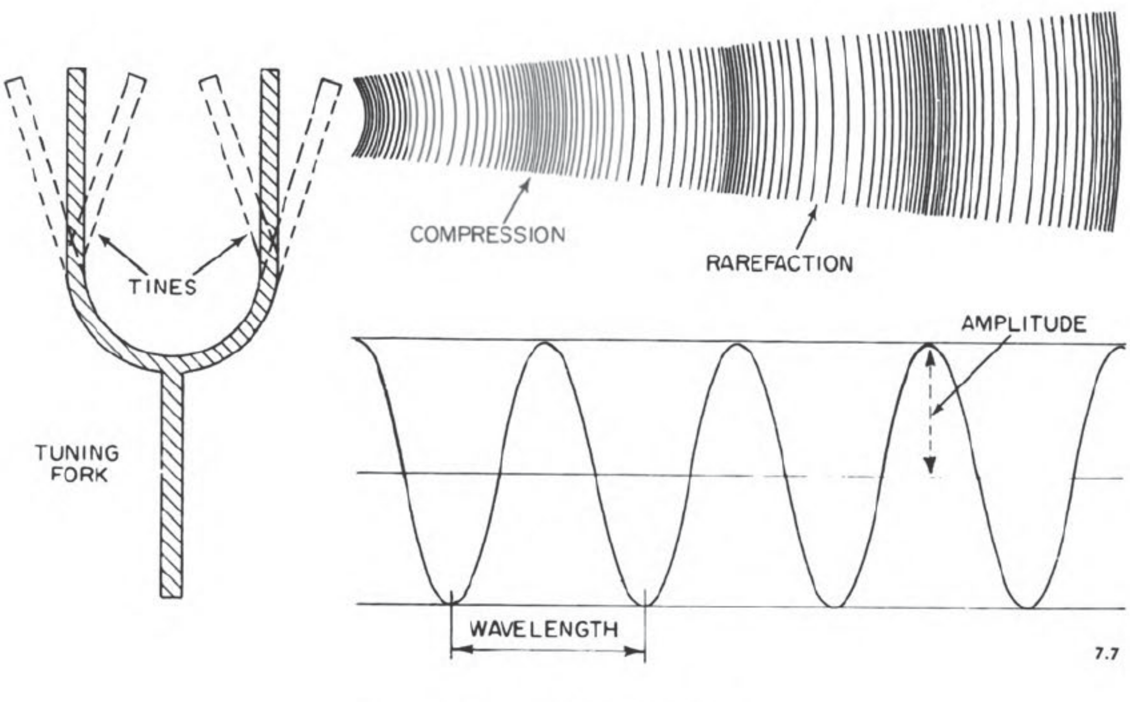


Figure 3-1.—Sound propagation.

The progress of any wave involves two distinct motions: (1) the wave itself moves forward with constant speed, and (2) simultaneously, the particles of the medium that convey the wave vibrate harmonically. (Examples of harmonic motion are the motion of a clock pendulum, a swing, the balance wheel in a watch, and the piston in a gas engine.)

The period of a vibrating particle is the time in seconds t required for the particle to complete one vibration.

The frequency f is the number of vibrations completed per second and may be expressed in cycles per second (cps). When expressed in this unit, "cycles" means vibrations per second. The period is the reciprocal of the frequency $t = 1/f$.

The amplitude of vibration is the maximum displacement of the particle from its equilibrium position.

Two particles are in-phase when they are vibrating with the same frequency, and continually pass through corresponding points of their paths at the same time. For any other condition the particles are out-of-phase. The two particles are in-phase opposition when they reach their maximum displacements in opposite directions at the same time.

The wavelength is the distance measured along the direction of propagation between two corresponding points of equal intensity that are in-phase on adjacent waves. This length can be represented by the distance between the adjacent maximum compression points in the traveling sound wave (fig. 3-1).

VELOCITY OF SOUND

As previously stated, a sound wave is a compressional wave transmitted through an elastic medium. The speed of sound is affected by the density and elasticity of the medium through which it is traveling. Sound travels faster through water (4800 ft/sec) than air (1087 ft/sec) because the elasticity of water is greater than that of air.

For a fixed temperature, the velocity of sound is constant for any medium and is independent of the period, frequency, or amplitude of the disturbance. Thus, the velocity of sound in air at 0° C (32° F) is 1087 feet per second (fps) and increases by 2 fps for each degree Centigrade rise in temperature (1.1 fps for each degree Fahrenheit).

A body vibrating at a definite rate produces a disturbance that moves away as a wave in the surrounding medium. The velocity of this wave is equal to the wavelength divided by the period. Since the period is the reciprocal of the frequency, the velocity is

$$v = f\lambda \tag{3-1}$$

where v is the velocity of sound in feet per second, f the frequency in vibrations per second, and λ the wavelength in feet.

CHARACTERISTICS OF SOUND

The word "sound" is used to denote hearing and also to denote the vibratory motion of a sound source. The word sound is used in acoustics in the latter sense.

Numerous terms are used to convey impressions of sounds, including whistle, scream, rumble, and hum. Most of these are classified as noises in contrast to musical tones. The distinction is based on the regularity of the vibrations, the degree of damping, and the ability of the ear to recognize components having a musical sequence.

The ear can distinguish tones that are different in pitch, intensity, or quality. Each of these characteristics is associated with one of the properties of the vibrating source or of the waves that the source produces. Thus, pitch is determined by the number of vibrations per second; intensity, by the amplitude of the wave motion; and quality, by the number of overtones (harmonics) which the wave contains. A sound wave can best be described by its frequency rather than by its velocity or wavelength, as both the velocity and the wavelength change when the temperature of the air changes.

Pitch

The term pitch is used to describe the frequency of a sound. The outstanding recognizable difference between the tones produced by two different keys on a piano is a difference in pitch. The pitch of a tone is proportional to the number of compressions and rarefactions received per second, which in turn is determined by the vibration frequency of the sounding source.

Pitch is usually measured by comparison with a standard. The standard tone may be produced by a tuning fork of known frequency or by a siren whose frequency is computed for a particular

speed of rotation. By regulating the speed, the pitch of the siren is made equal to that of the tone being measured. The ear can determine this equality directly if the two sources are sounded alternately, or by the elimination of beats by regulating the speed of the siren if the two sources are sounded together.

Intensity

When a bell rings, the sound waves spread out in all directions and the sound is heard in all directions. When a bell is struck lightly, the vibrations will be of small amplitude and the sound will be weak. A stronger blow will produce vibrations of greater amplitude in the bell, and the sound will be louder. It is evident that the amplitude of the air vibrations is greater when the amplitude of the vibrations of the source is increased. Hence, the loudness of the sound depends on the amplitude of the vibrations of the sound waves. As the distance from the source increases, the energy in each wave spreads out, and the sound becomes weaker.

The intensity of sound is the energy per unit area per second. In a sound wave of simple harmonic motion, the energy is half kinetic and half potential; half is due to the speed of the particles, and half is due to the compression and rarefaction of the medium. These two energies are 90 degrees out-of-phase at any instant. That is, when the speed of particle motion is at a maximum, the pressure is normal and when the pressure is at a maximum or a minimum, the speed of the particles is zero.

The loudness of sound depends upon both intensity and frequency. The intensity of a sound wave in a given medium is proportional to the (1) square of the frequency of vibration, (2) square of the amplitude, (3) density of the medium, and (4) velocity of propagation. At any distance from a (point) source of sound the intensity of the wave varies inversely as the square of the distance from the source.

As a sound wave advances, variations in pressure occur at all points in the transmitting medium. The greater the pressure variations, the more intense the sound wave will be. It can be shown that the intensity is proportional to the square of the pressure variation regardless of the frequency. Thus, by measuring pressure changes, the intensities of sounds having different frequencies can be compared directly.

Quality

Most sounds and musical notes are not pure tones. They are mixtures of tones of different frequencies. The tones produced by most sources can be represented by composite waves in which the sound of lowest pitch, the fundamental tone, is accompanied by several harmonics or overtones having frequencies that are 2, 3, 4 or more times that of the fundamental frequency. The quality of a tone depends on the number of overtones present and on their frequencies and intensities relative to the fundamental tone. It is this characteristic of difference in quality that distinguishes tones of like pitch and intensity when sounded on different types of musical instruments (piano, organ, violin, and so forth).

PROPERTIES OF WAVE MOTION

A wavefront is a surface of which all points are vibrating in phase. When an advancing wave encounters a medium of different character, some of its energy is reflected back into the initial medium, and some is transmitted into the second medium.

Reflection

When a sound wave encounters a medium through which it cannot penetrate, the wave is reflected at the boundary surface.

In explaining reflection of waves, it is helpful to think of the wave as a ray. A ray is a line which indicates the direction the wave is traveling. In a uniform medium, a ray will travel in a straight line. Only at the boundary of two media or in an area where the medium is changing do the rays change their direction.

If a line, called a normal, is drawn perpendicular to a boundary the angle between an incoming ray and this normal is called the angle of incidence i, as shown in figure 3-2. The angle which the ray being reflected makes with the normal is called the angle of reflection r. Any wave being reflected is reflected in such a way that the angle of incidence equals the angle of reflection.

Light is often thought of first whenever reflection is discussed, however, reflection is equally common in other waves. As an example, echoes are caused by reflection of sound waves.

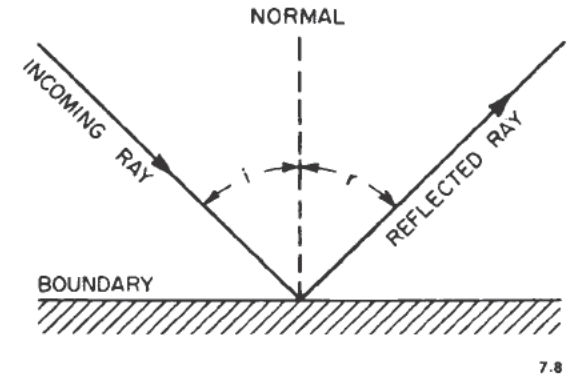


Figure 3-2.—Reflection of a ray.

Reflected waves in water are also common especially in the use of sonar equipment.

Refraction

When a sound wave passes at an angle from one medium to another, it is deflected toward or away from the normal, depending on the density of the medium (fig. 3-3). This deflection is known as refraction. If the wave passes from a less dense to a more dense medium, it is bent toward the normal, and the angle of refraction r is less than the angle of incidence i. Likewise, if the wave passes from a more dense to a less dense medium, it is bent away from the normal, and the angle of refraction r_1 is greater than the angle of incidence i_1. Both of these conditions are illustrated in figure 3-3, A.

Refraction can be more readily understood if the incident wave is assumed to be a company of recruits marching four abreast from a parade ground to a plowed field (fig. 3-3, B). Marching diagonally across the parade ground to the plowed field, each man in the front line will be slowed down as he crosses the boundary. Because the men arrive at the boundary at different times, they will begin to slow down at different times (number 1 slows down first and number 4 slows down last in each line). The net effect is a bending action. When the men leave the plowed field and reenter the parade ground, the reverse action takes place.

Interference of Waves

Two sound waves moving through the same medium at the same time will advance independently, each producing the same disturbance as if it were alone. The resultant of the two waves can be obtained by adding algebraically the ordinates (instantaneous magnitudes) of the component waves.

Two sound waves of the same frequency, in phase with each other and moving in the same direction are additive. The resultant wave is in phase with, and has an amplitude equal to the sum of the component waves.

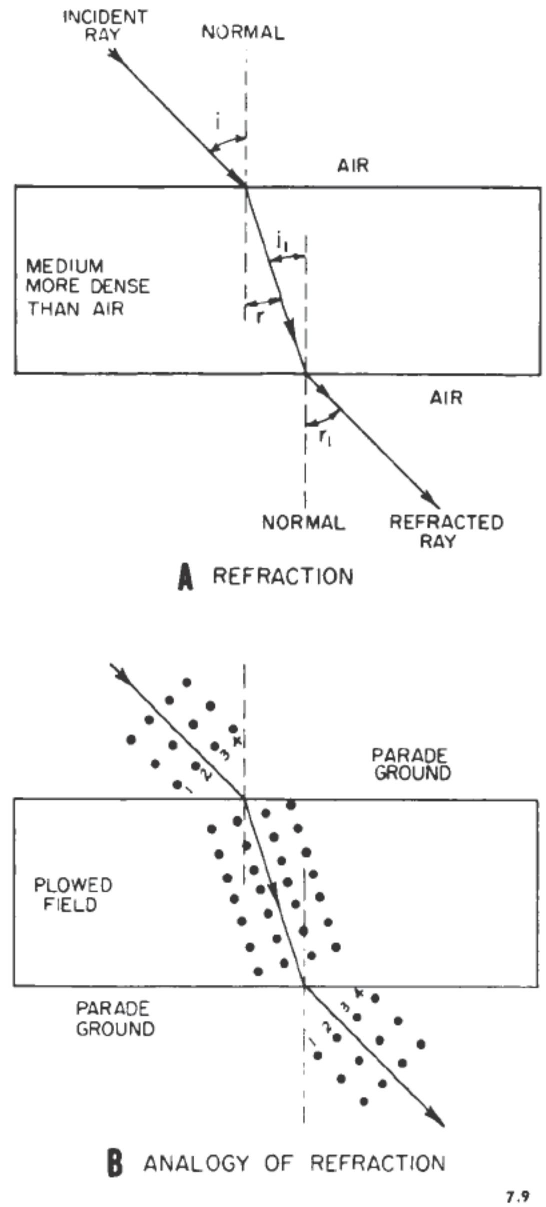


Figure 3-3.—Portion of a sound wave transmitted through a medium.

Two sound waves of the same frequency, in phase opposition and moving in the same direction are subtractive. If the component waves have equal amplitudes, the resultant wave is zero. This addition or subtraction of waves is often called interference.

Two sound waves of slightly different frequency and moving in the same direction produce a beat note. If the two waves originate from two vibrating sources at the same point, and the frequency of one wave is one vibration per second greater than that of the other at a particular instant, the sources will produce additive disturbances at some points and subtractive disturbances at some other points on the relative positions of the waves. These changes will continue to occur as long as the sources are kept vibrating.

The resultant wave has a periodic variation in intensity at a frequency equal to the difference between the original frequencies of the component waves. This difference frequency, referred to as the beat frequency, produces a type of pulsating interference that is particularly noticeable in sound waves. The effect of beat frequency, called beats, produces alternately loud and soft pulses or throbs. The effect is most pronounced when the component waves have equal amplitudes.

Standing Waves

Two sound waves of equal frequency and amplitude moving in opposite directions through the same medium may produce standing waves. These standing waves are set up when at certain points the waves are in-phase while at others they are 180 degrees out-of phase.

These standing waves are set up by the reaction of the two waves on each other. At certain points they are in-phase and at other points they are 180 degrees out-of-phase. Because their amplitudes are equal, when the two waves act in opposition on a particle the particle remains motionless. At these points in a standing wave, there is no vibration and the points are called nodes. At the points where the two waves reinforce each other they produce maximum vibrations on a particle. These points are called antinodes. The distance between successive nodes (or antinodes) is a half wavelength.

Resonance

Assume that the natural frequency of vibration of a steel shaft weighted on one end and firmly held on the other is 25 vibrations per second. Suppose with the system at rest, a force acts on it with a to-and-fro motion of 125 times per second. This will set the system vibrating at 125 vib/sec, but with small amplitude because the rod and weight are trying to vibrate at their natural rate of only 25 vib/sec. Thus during part of the time the system is resisting the driving force. The motion of the system in this case is called a forced vibration.

If the force is slowed from 125 vib/sec to its natural frequency of 25 vib/sec, the amplitude of vibration becomes very large. The amplitude will build up to a point where the driving force is just enough to overcome the friction of the system. When these conditions exist the system is said to be in resonance with the driving force.

Resonant vibrations may present a serious problem aboard ship, particularly with heavy machinery. It is often necessary to find the part of an equipment that is vibrating in resonance with a heavy piece of machinery and to change the natural frequency of the vibrating part. This can be done by changing either its mass or speed.

A common example of resonance encountered by the IC Electrician is found in a crystal oscillator circuit. When an alternating voltage is applied to a crystal that has the same mechanical (resonant) frequency as the applied voltage, it vibrates and only a small applied voltage is needed to sustain vibration. In turn, the crystal generates a relatively large voltage at its resonant frequency.

Doppler Effect

When there is relative motion between the source of a sound wave and a listener, the apparent frequency at the listening position differs from the frequency at the source. When a source of wave motion is moving toward a listener, more waves per second are encountered than when the source remains stationary. The effect at the listening position is an apparent increase in frequency. Conversely, when a source of wave motion is moving away from a

listener, fewer waves per second are encountered than when the source remains stationary. The effect at the listening position is an apparent decrease in frequency. These apparent changes in frequency are called Doppler effect. The amount of the change in apparent frequency depends on the relative velocity of the listener with respect to the source.

Acoustics

Acoustics is the science of sound, including its propagation, transmission, and effect. The performance of an announcing system or sound system when used in a room or enclosed space depends on the acoustical characteristics of the enclosure. Sound originating in an enclosed space is partly reflected and partly absorbed by enclosing surfaces such as the walls, ceiling, and floor of a room. This action introduces echoes and reverberations, which may seriously impair the quality or character of the sound.

An echo is the repetition of a sound caused by the reflections of sound waves. When a surface of a room is situated so that a reflection from it is outstanding, it appears as a distinct echo, and is heard an appreciable interval later than the direct sound. If the surface is concave, it may have a focusing effect and concentrate the reflected sound energy at one locality. Such a reflection may be several levels higher in intensity than the direct sound, and its arrival at a later time may be particularly disturbing. The possible remedies for this condition are to (1) cover the offending surface with absorbing material to reduce the intensity of the reflected sound, (2) change the contour of the offending surface and thus send the reflected sound in another direction, (3) relocate the loudspeaker, or (4) vary the amplitude or pitch of the loudspeaker signal. The best method to use depends on local conditions.

Reverberation is the persistence of sound due to the multiple reflection of sound waves between several surfaces of an enclosure. Excessive reverberation is one of the most common acoustical defects encountered in a large enclosure. The time that this residual sound persists varies directly with the time interval between reflections (the size of the enclosure) and inversely with the absorbing efficiency of the reflecting surfaces. The result is an overlapping of the original sound and its images. If excessive, this reverberation causes a general confusion that is detrimental to speech intelligibility. The hangar deck of an aircraft carrier is an example of an extremely reverberant area. The volume is large, and the hard steel interior surfaces offer very little absorption to sound.

If a single loudspeaker is mounted in a large reverberant area, such as a hangar deck, the intelligibility directly in front of the loudspeaker is satisfactory. The intelligibility decreases rapidly as either the distance from the loudspeaker or the angle off the loudspeaker sound axis is increased. In other words, sound from a loudspeaker in a reverberant space is composed of (1) direct sound that reaches the listener directly without any reflection, and (2) indirect sound that has received at least one reflection.

The direct sound intensity decreases inversely as the square of the distance from the source as it would in open air. The indirect sound intensity, on the other hand, increases when multiple rays of sound energy leave a loudspeaker. Each ray strikes some point on the surface of the room and is then reflected again and again, thus building up the amplitude of the sound. Each point of reflection may be considered as a new source of sound. Hence, a large number of these image sources is established so that sound distribution in a room tends to remain substantially uniform.

Intelligibility under these conditions is related to the ratio of direct to indirect sound. Thus, as the listener moves away from the loudspeaker, the ratio of direct to indirect sound at the listening position decreases, and the intelligibility decreases correspondingly. Hence, in a highly reverberant space the intelligibility decreases with distance from the loudspeaker.

To prevent the sound from becoming unintelligible in a highly reverberant space, several speakers can be installed about the area rather than just one. The power consumption would remain the same, i.e., one 25-watt speaker could be replaced by 5 speakers, each consuming 5 watts. This would greatly increase the direct to indirect sound ratio.

MEASUREMENT OF SOUND

The range of sound that the human ear can detect varies with the individual. The average

range extends from about 20 to 20,000 vibrations per second. In the faintest audible speech sounds, the intensity at the ear is about 10^{-16} watts/cm^2. At the threshold of feeling, the maximum intensity that the ear records as sound is about 10^{-4} watts/cm^2.

The human ear is a nonlinear unit that functions on a logarithmic basis.

If the ear is tested with tones of any one frequency the threshold of audibility is reached when the intensity is reduced to a sufficiently low level so that the auditory sensation ceases. On the other hand, the threshold of feeling is reached when the intensity is increased to a sufficiently high level so that the sound produces the sensation of feeling and becomes painful. If this procedure is performed over a wide frequency range, the data can be used to plot two curves, one for the lower limit of audibility and the other for the maximum auditory response (fig. 3-4). Below the lower curve the sound is too faint to be audible. Above the upper curve the sensation is one of feeling rather than of hearing—that is, the sensation of sound is masked by that of pain. The area between the two curves shows the pressure ranges for auditory response at various frequencies. Note that the scales of frequency and pressure are logarithmic. An advance of one horizontal space doubles the frequency, and an advance of one vertical space multiplies the pressure by ten.

Bel

The loudness of sound is not measured by the same type of scale used to measure length. Units of sound measurement are used that vary logarithmically with the amplitude of the sound variations. These units are the bel and decibel, which refer to the difference between sounds of unequal intensity or sound levels. The decibel, which is one-tenth of a bel, is the minimum change of sound level perceptible to the human ear. Hence, the decibel merely describes the ratio of two sound levels. A sound for which the power is 10 times as great as that of another sound level differs in power level by 1 bel, or 10 decibels. For example, 5 decibels may represent almost any volume of sound, depending on the intensity of the reference level or the sound level on which the ratio is based.

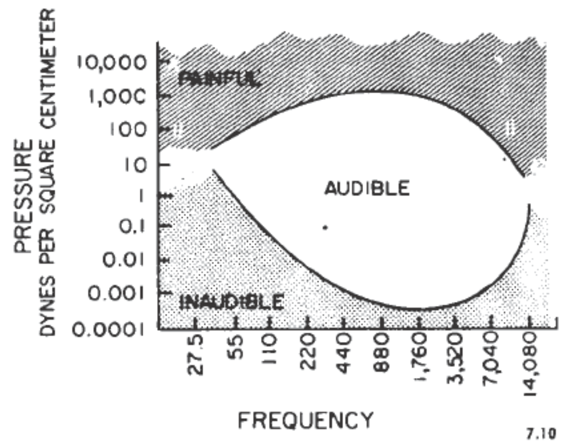


Figure 3-4.—Field of audibility.

In sound system engineering, decibels are used to express the ratio between electrical powers or between acoustical powers. If the amounts of power to be compared are P_1 and P_2, the ratio in decibels (db) is

$$db = 10 \log_{10} \frac{P_2}{P_1} \qquad (3-2)$$

If P_2 is greater than P_1, the decibel value is positive and represents a gain in power. If P_2 is less than P_1, the decibel value is negative and represents loss in power.

Sound-intensity Level

An arbitrary zero reference level is used to accurately describe the loudness of various sounds. This zero reference level is the sound produced by 10^{-16} watts per square centimeter of surface area facing the source. This level approximates the least sound perceptible to the ear and is usually called the threshold of audibility. Thus, the sensation experienced by the ear when subjected to a noise of 40 decibels above the reference level would be 10,000 times as great as when subjected to a sound that is barely perceptible.

Acoustical Pressure

Typical values of sound levels in decibels and the corresponding intensity levels are summarized in table 3-1. The values in this table are based on an arbitrary zero reference level.

Table 3-1.—Values of Sound Levels.

Sound level (decibels)	Intensity level (watts/cm^2)
0.	10^{-16}
60.	10^{-10}
80.	10^{-8}
100	10^{-6}
110	10^{-5}
120	10^{-4}
130	10^{-3}

Note that for each tenfold increase in power, the intensity of the sound increases 10 decibels. The power intensity doubles for each 3-decibel rise in sound intensity.

Power Ratio

The decibel is used to express an electrical power ratio, such as the gain of an amplifier, the output of a microphone, or the power in a circuit compared to an arbitrary reference power level. The value of decibels is often computed from the voltage ratio squared or the current ratio squared. These are proportional to the power ratio for equal values of resistance. If the resistances are not equal, a correction must be made.

To find the number of decibels from the voltage ratio, assuming that the resistances are equal, substitute in the equation (3-2)--

$$db = 20 \log \frac{E_2}{E_1} \tag{3-3}$$

To find the number of decibels from the current ratio, assuming that the resistances are equal, substitute in the equation (3-3)--

$$db = 20 \log \frac{I_2}{I_1} \tag{3-4}$$

The power level of an electrical signal is often expressed in decibels above or below an arbitrary power level of 0.001 watt (1 milliwatt) as

$$dbm = 10 \log_{10} \frac{P}{0.001} \tag{3-5}$$

where dbm is the power level above one milliwatt in decibels, and P is the power in watts.

The volume level of an electrical signal comprising speech, music, or other complex tones is measured by a specially calibrated voltmeter, called a volume indicator. The volume levels read with this indicator are expressed in "vu units," the number being numerically equal to the number of decibels above or below the reference volume level. Zero vu represents a power of 1 milliwatt dissipated in an arbitrary load resistance of 600 ohms (corresponds to a voltage of 0.7746 volt). Thus, when the vu meter is connected to a 600-ohm load, vu readings in decibels can be used as a direct measure of power above or below 1 milliwatt. For any other value of resistance the following correction must be added to the vu reading to obtain the correct vu value:

$$vu = vu\ reading + 10 \log \frac{600}{R} \tag{3-6}$$

where vu is the actual volume level, and R is the actual load, or resistance, across which the vu measurement is made. If the volume levels are indicated in other than vu units, the meter calibration, or reference level, must be stated with the decibel value.

ASPECTS OF SOUND SYSTEMS

All sound and announcing systems consist basically of a microphone, an amplifier, and a loudspeaker. The microphone converts the sound energy into electrical energy having the same waveform as the sound energy. The output from the microphone is applied as a signal voltage to the amplifier. The output power from the amplifier has the same waveform as the sound energy applied to the microphone. The loudspeaker reconverts the electrical energy from the amplifier into sound energy at a higher volume level then the original sound. In shipboard installations many loudspeakers are operated from the same amplifier. Each

loudspeaker produces sound having the same waveform as the original sound applied to the microphone.

When one or more microphones, amplifiers, and loudspeakers are connected together to comprise a sound system or an announcing system, additional problems are introduced, which must be considered. These problems are treated in the following paragraphs.

DISTORTION

Distortion is said to be present in an amplifier or other audio device when the output signal differs in waveform from that of the input signal. The types of distortion commonly encountered in sound systems are (1) frequency, (2) nonlinear, (3) phase, and (4) intermodulation distortion.

Frequency Distortion

Frequency distortion occurs when the gain or loss of a device is not the same at all frequencies. This factor determines the frequency range of a sound system. This type of distortion is present because sound systems are unable to amplify all frequencies by exactly the same amount. The statement of the frequency range of a sound system usually specifies the operating band of frequencies and the maximum amplitude distortion within this band.

Nonlinear Distortion

Nonlinear distortion is the type of distortion that introduces frequencies at the output of a system, which are not present at its output. A certain amount of nonlinear distortion is always present in sound systems, but the magnitude is small and can be ignored until the load-carrying capacity of some part of the system is approached. Nonlinear distortion limits are specified at a definite power output, which is usually the maximum power that the system is expected to handle. The limits are usually specified at some maximum permissible percentage of harmonics, such as 5 or 10 percent.

Phase Distortion

Phase distortion occurs when two or more frequencies bearing a certain phase relationship to each other are transmitted by a device in such a manner that this phase relationship is altered. This type of distortion is of little importance in sound systems.

Intermodulation Distortion

Intermodulation distortion occurs when two or more different frequencies are transmitted in such a way that new frequencies are generated as intermodulation products. In other words, if the original signal contains frequencies of values f_1 and f_2, it is possible for new frequencies to be produced of values $f_1 + f_2$, $f_1 - f_2$, $2f_1 + f_2$, $2f_1 - f_2$, $f_1 + 2f_2$, and so forth. This type of distortion, if present to any marked degree, can be particularly objectionable because the new sum and difference frequencies bear no harmonic relation to the original.

IMPEDANCE MATCHING

When a source or generator of electrical power having a certain internal impedance is connected to a load, the percentage of the available power, which can be transferred to the load, depends upon the load impedance. A maximum amount of power will be delivered to the load when load impedance is equal to the internal impedance of the generator. Under this condition the impedances of the generator and load are said to be matched. Impedance matching can be accomplished when the generator and load impedances are different by employing a suitable impedance matching transformer between the generator and the load.

In the design of audio amplifiers, distortion and output voltage regulation must also be considered because these factors may dictate other than a perfect impedance match between the amplifier and the loudspeaker for optimum system performance. In such cases, the amplifier design output impedance is set at a value appreciably lower than that of the loudspeaker load impedance. This condition provides maximum undistorted power transfer at a voltage, which will be substantially independent of the number of loudspeakers connected to the amplifier.

AUDIO OUTPUT POWER DISTRIBUTION

The distribution of audio output power to a large number of loudspeakers in a sound

system can be accomplished by means of a (1) constant impedance, or (2) constant voltage system.

Constant Impedance System

In a constant impedance system, the amplifier is designed to operate into a fixed load impedance. The amplifier characteristics, such as frequency response, may be adversely affected if any other impedance is connected to its output terminals, and the output level of the loudspeakers connected to such a system may vary considerably when different loudspeaker groups are connected to or disconnected from the system. This type of system requires that substitute load resistors be added when a loudspeaker is disconnected. This action results in additional heating within the amplifier rack and in additional power consumption from the power supply mains.

The system also requires a wide range of impedance adjustment in the matching transformers of the individual loudspeakers. This is necessary so that the combined impedance of each group can be made equal to a fixed value irrespective of the number, types, and power ratings of the loudspeakers in the group. Such a system requires a complete design study for each installation to determine the proper impedance settings for each type of loudspeaker in each group.

Constant Voltage System

In a constant voltage system, the amplifier is designed to deliver power at a substantially constant output voltage within specified distortion limits to any loudspeaker load up to the load that draws rated output power from the amplifier. In this system, the loudspeakers or loudspeaker groups can be added or disconnected without requiring any system adjustment or necessitating any balancing or loading resistors. The only adjustment that may be necessary is at the loudspeaker matching transformer to raise or lower the output level at that loudspeaker. Future shipboard announcing systems will be of the constant voltage type.

AUDIO TRANSMISSION LINES

An audio transmission line, or lines, is a pair of conductors connecting an amplifier to a group of loudspeakers. Transmission lines have resistance in the conductors and distributed capacitance between the conductors. These properties have an effect on the performance of the sound system and must be considered in the design of the system.

The terms, low impedance line and high impedance line, when used concerning sound distribution do not refer to any inherent property of the line proper. These terms mean that the line conductors are attached to a high impedance or to a low impedance load. The line impedance may be set at any desired value for transmission purposes because an output transformer is used at the amplifier, and individual matching transformers are used at each loudspeaker in the shipboard announcing system. The optimum value at which to set the impedance is determined by the following considerations.

If the line impedance is set at a low value for a given amount of power transmitted, the current will be high and the voltage low. This condition will result in the high line loss (I^2R) in the form of heating the copper conductors, and less power will be available to drive the loudspeakers. Larger diameter wire (heavier cables) will be required to lower the line resistance and thereby reduce the line loss in this case.

If the line impedance is set at a high value, the capacitive reactance of the distributed capacity between the conductors will approach the line impedance value at higher frequencies. This condition results in a shunting effect across the loudspeaker load and reduces the voltage available at the loudspeaker at higher frequencies. Thus the high frequency response of the system will be attenuated and the intelligibility of the speakers impaired.

An optimum value of line impedance can be selected for any given system within the extreme limits described above. For shipboard announcing systems of the constant impedance type, 50-ohm lines have been commonly employed. For shipboard announcing systems of the constant voltage type in which operating voltages from 70 to 100 volts have been employed, the resulting line impedances have ranged from approximately 50 to 1,000 ohms, depending on the number of loudspeakers connected to the group.

INDUCED SYSTEM NOISE

In a sound or announcing system, the wires connecting the microphones to the input of the amplifier are usually referred to as input or low-level lines. If the wires are subjected to external electrical fields, voltages will be introduced into the input circuit of the amplifier and will appear in the output of the system as noise in the form of hum or static disturbances.

Microphone noise can be greatly reduced by keeping the leads short, by shielding, and by making solid connections. Microphone noises are caused by magnetic pickup, static pickup, and longitudinal currents.

Magnetic Pickup

Magnetic pickup is the induced emf picked up by a wire lying in a magnetic field of a conductor carrying a varying current. The disturbance caused by this induced emf can be reduced by using twisted pairs of wire which tend to neutralize the induced emf in each wire.

Spacing is often an effective way of reducing the effects of an induced emf. The greater the spacing between a wire and a magnetic field the less effect the field will have on it.

Shielding reduces magnetic pickup by providing an easy path for the magnetic field to follow. This path is away from the circuits being protected.

Static Pickup and Longitudinal Currents

Static pickup is the interference induced electrostatically in a wire from the electric field caused by the difference in potential of two other wires. It can be reduced by grounding and shielding.

Longitudinal currents (noise currents) are currents induced in a pair of wires by an electrostatic field. These longitudinal currents flow in the same direction in both wires while normal signal currents flow in opposite directions. The resulting interference appears as noise in the system.

The usual protection against longitudinals is a grounded static shield between the windings of an input transformer. This arrangement drains the noise currents to ground before they reach a place where they become troublesome.

OUTPUT CIRCUIT PROTECTION

In certain shipboard applications, a portion of the announcing system is installed within a protective armor belt and is well protected against battle casualties. The remainder of the circuit, consisting mainly of loudspeakers and loudspeaker cables, is installed outside the protective enclosure and is vulnerable to damage. Because all loudspeakers are connected in parallel, any circuit fault that may occur in the nature of a short circuit will effectively short circuit the amplifier output and render the entire system inoperative. In such cases, series protective resistors are employed in the loudspeaker lines.

Series Protective Resistors

Series protective resistors have the effect of lowering the voltage available at the loudspeaker terminals so that the loudspeaker matching transformer impedance must be readjusted so that it can draw the rated power from the line. On systems of this type, transformer tap connections are provided for this purpose. If there is a short-circuited output line on such an installation, an additional load is placed on the amplifier, but the series resistors prevent the short circuit from disabling the system.

Subgroup Cutout Switches

In all general announcing systems, the circuits for each loudspeaker group (such as officers, crew, topside, and engineers) are routed through the interior communication and action cutout switchboards where the circuits are divided into subgroups of approximately 10 loudspeakers each. Each subgroup is provided with an individual cutout switch to permit disconnecting the subgroup in case of a circuit fault.

ACOUSTICAL FEEDBACK

When the microphone is located too close to a loudspeaker in announcing systems, it is possible for some of the sound output to be picked up by the microphone and reamplified until a sustained howl is set up. This action is referred to as acoustical feedback, or singing.

To prevent feedback, it is necessary to make the loss in the acoustical path from the loudspeaker to the microphone greater than the gain in the sound system from the microphone to the loudspeaker. This loss includes the loss involved in converting sound to electrical energy in the microphone and in converting electrical energy to sound in the loudspeaker. The following discussion describes the method by which feedback can be avoided or minimized in naval applications.

In a general announcing system, local loudspeaker cutouts are provided for the loudspeakers located in the same compartment or adjacent to a microphone station to automatically disconnect the offending loudspeakers when that particular microphone is in use.

Specially designed close-talk microphones can be employed to discriminate against distant sounds and to favor sound originating close to the microphone. Microphones of directional characteristics can also be used to advantage for this application.

Feedback can be avoided by increasing the distance between the loudspeaker and the microphone, and by keeping the microphone behind or outside of the beam of the loudspeaker. This arrangement is possible in the use of portable announcing systems, such as the Beachmaster, in which the relative location of loudspeaker and microphone can be varied.

When the relative locations of microphone and loudspeaker are fixed and close-talking microphones are being employed, as in the flight deck announcing system of an aircraft carrier, the amplifier gain must be reduced to the point in which feedback will not occur. In these cases, the reduced amplifier gain must be compensated for by increasing the level of the input speech signal. This condition requires holding the microphone close to the lips and talking in a loud, firm voice.

QUIZ

1. What condition must exist in a body for sound to be produced?
2. Name two classes of waves.
3. In what direction do the particles of the medium vibrate in a transverse wave?
4. In what direction do the particles of the medium vibrate in a longitudinal wave?
5. Why are sound waves in a gas or liquid considered as longitudinal waves?
6. What is the nature of a sound wave produced by the tines in figure 3-1?
7. What is the period of a vibrating particle in a medium?
8. What is the frequency of vibration?
9. What is the amplitude of vibration?
10. When are two vibrating particles in phase?
11. When are two vibrating particles in phase opposition?
12. What is the wavelength of a sound wave?
13. Name the three qualities of a medium that affect the velocity with which sound disturbances are transmitted through the medium.
14. Name the three terms that are used to describe the characteristics of sound.
15. What determines the pitch of a sound, or tone?
16. What determines the intensity of a sound?
17. What is the sound of lowest pitch called?
18. Upon what does the quality of a tone depend?
19. What occurs when a sound wave encounters a medium through which it cannot penetrate?
20. What occurs when a sound wave passes at an angle from one medium into another medium and the velocity of the wave in one medium is different from that in the other medium?
21. What kind of interference is produced by two sound waves of the same frequency, in phase with each other, and moving in the same direction?
22. What kind of interference is produced by two sound waves of the same frequency, in phase opposition, and moving in the same direction?
23. What is the name given to the periodic vibrations in intensity resulting from additive and subtractive disturbance produced by two sound waves of different frequencies and moving in the same direction?
24. What is the effect of beat frequency?
25. What is the effect called when conditions are such that the period of forced vibration is the same as that of the free vibration and the two effects strengthen each other, resulting in larger amplitudes of the vibrating body?

26. What are the apparent changes in pitch called when there is a relative motion between the sound source and the listener?

27. What is the science of sound called which includes its propagation, transmission, and effect?

28. What is the repetition of a sound called that is caused by the reflections of sound waves?

29. What is the persistence of sound called that is due to the multiple reflection of sound waves between several surfaces of an enclosure?

30. What unit is used to describe the ratio of the power of two sound levels?

31. What is the meaning of the expression, threshold of audibility?

32. What type of distortion occurs in an audio amplifier when the gain or loss is not the same at all frequencies?

33. What type of distortion introduces frequencies at the output of a system that are not present at its input?

34. How can impedance matching with resulting maximum power transfer be accomplished in a system when the generator and load impedance are different?

35. What is the advantage of the constant voltage system compared with the constant impedance system in the distribution of audio output power to a large number of loudspeakers in a sound system?

36. Name the two properties of an audio transmission line that affect the performance of the sound system and which must be considered in the design of the system.

37. What is the effect on the line loss and available power to drive the loudspeakers in a system if the line impedance is set at too low a value?

38. What is the effect on the distributed capacity between the conductors and the voltage available at the loudspeakers at higher frequencies in a system if the line impedance is set at too high a value?

39. What are the input, or low-level, lines in a sound system?

40. What undesirable condition results if the input lines of a sound system are subjected to external electrical fields?

41. Name the three types of induced noise that may be encountered in a sound system.

42. What is the technical name for the distortion effect that appears in the system output when the microphone is located near a loudspeaker and too much of the sound output is picked up by the microphone?

CHAPTER 4

MICROPHONES AND LOUDSPEAKERS

This chapter describes the types, maintenance and characteristics of microphone equipment used in naval sound and communicating systems. Also included is a similar treatment of the loudspeakers used in these systems.

MICROPHONES

A microphone is a device that converts sound energy into electrical energy. The microphones in common use (described in chapter 9 of *Basic Electronics)* include the (1) magnetic, (2) dynamic, (3) crystal, and (4) carbon types. All microphones consist of a member that responds to the vibrations of the sound waves and a means of changing the mechanical vibrations into corresponding electrical signals. The various types differ mainly in the driving mechanism, or method of conversion from mechanical motion into electrical energy. The magnetic and dynamic types of driving mechanisms are most commonly used in naval announcing systems.

DRIVING MECHANISMS

The magnetic, or moving-armature, microphone illustrated in figure 4-1 consists of a permanent magnet and a coil of wire inside of which is a small armature. The armature is coupled to the diaphragm by a drive rod. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration is transmitted through the drive rod to the armature, which vibrates in a magnetic field, thus changing the magnetic flux through the armature.

When the armature is in its normal position, midway between the two poles, the magnetic flux is established across the air gap with no resultant flux in the armature.

When a compression wave strikes the diaphragm, the armature is deflected to the right. The flux path is directed from the north pole of the magnet across the reduced gap at the upper right, down through the armature, and around to the south pole of the magnet.

When a rarefaction wave strikes the diaphragm, the armature is deflected to the left. The flux path is now directed from the north pole of the magnet, up through the armature, across the reduced gap at the upper left, and back to the south pole.

Thus, the vibrations of the diaphragm cause an alternating flux in the armature. The alternating flux cuts the stationary coil wound around the armature and induces an alternating voltage in it. This voltage has the same waveform as the sound waves striking the diaphragm.

The magnetic microphone is most widely used in shipboard announcing and intercommunicating systems because it is highly resistant to vibration, shock, and rough handling.

The dynamic, or moving-coil, microphone (fig. 4-2) consists of a coil of wire attached to a diaphragm, and a radial magnetic field in which the coil is free to vibrate. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration moves the voice coil through the magnetic field so that the turns cut the lines of force in the field. This action generates a voltage in the coil that has the same waveform as the sound waves striking the diaphragm.

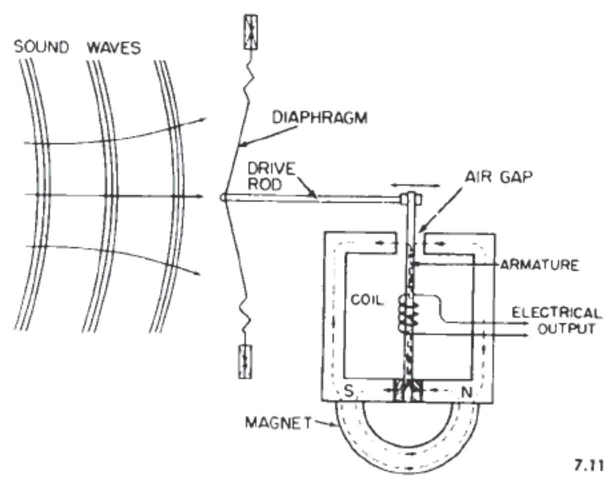


Figure 4-1.—Magnetic microphone.

The dynamic microphone requires no external voltage source, has good fidelity, and produces an output voltage of about 0.05 volt when spoken into in a normal tone within a few inches of the diaphragm.

CONSTRUCTION

The portable magnetic microphone (fig. 4-3) is designed for use in interior communication systems, which provide amplification for the microphone output. The microphone output for normal speech directly into the mouthpiece is of the order of 10 mv across a 150-ohm resistive load. Sufficient amplification must be provided to raise the power level to drive the system loudspeakers or telephone receivers.

The microphone consists of a microphone housing containing the microphone element, talk switch, and a 6-foot cable terminated with a male connector plug. The two-section housing is made of molded bakelite with a cylindrical nickel-plated brass insert in the front section to provide for mounting the microphone element. The talk switch (pushbutton) is located in a watertight mounting in the top of the housing so that it can readily be operated by the thumb or index finger of either hand.

A circular seal plug or moisture barrier (not shown), made of a porous ceramic material, is located in the rear section of the housing to provide for the equalization of air pressure between the front and rear of the microphone element. The seal plug is watertight but equalizes for slow changes in atmospheric pressure.

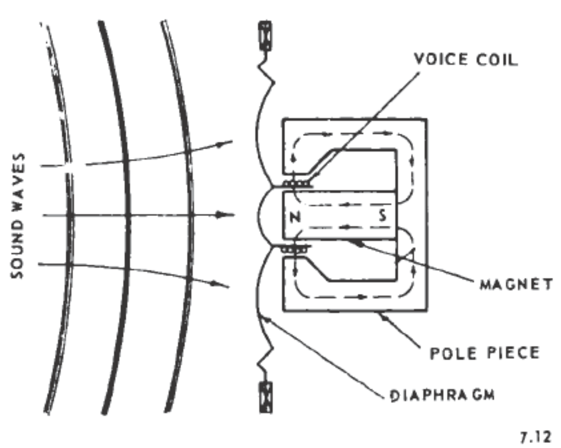


Figure 4-2.—Dynamic microphone.

A 6-foot, Navy-type MCOS-5, five-conductor, rubber-covered cable connects the microphone to a watertight, 6-prong male plug, which is provided for making connections with a receptacle or microphone control box, as required.

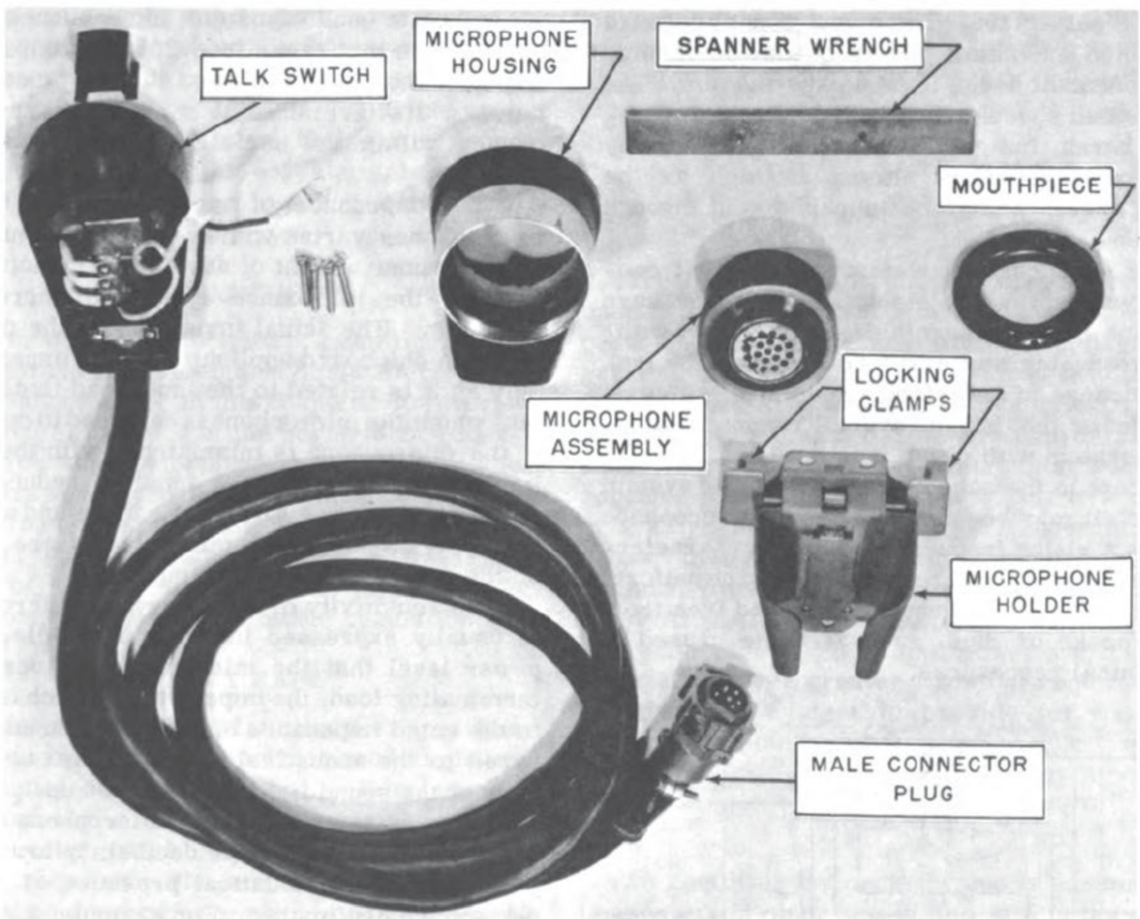
The wiring diagram of the portable microphone is illustrated in figure 4-4. The microphone cable passes through a watertight bushing into the microphone housing, and the leads are connected to the microphone element and to the talk-switch terminal board. The talk switch is a pile-up contact assembly having three terminals, the operation of which provides for successive closure of two circuits using a common return.

When the microphone is in standby use, it is stowed in a holder designed for bulkhead mounting (fig. 4-3). The holder is a metal bracket, provided with a spring-loaded contact, which grips the microphone housing to prevent it from jarring loose. To operate the microphone, press on one of the locking clamps to release the spring tension, and lift it from the holder. If the circuit is available, close the selector switch or switches and energize the amplifier by pressing the microphone talk switch. Speak distinctly into the microphone, using the prescribed microphone technique. Do not close the talk switch until just before making the announcement. Release the talk switch immediately after the announcement is made, open the selector switches, and return the microphone to the holder.

MAINTENANCE

The portable microphone is of sturdy construction; therefore, with reasonable care it should require little attention. Unauthorized personnel should not remove the element from the housing, or tamper with the unit in any way. Any foreign object inserted through the mouthpiece of the unit can damage the diaphragm.

If an intercommunication system should fail to operate from a particular microphone station, isolate the fault by substituting a microphone known to be in good operating condition. If the fault is in the portable microphone assembly, make a continuity check at the plug terminals to determine if the switch operates properly. If the diaphragm and armature are free, the microphone will give a distinct click when its circuit is checked with an ohmmeter. Check the d-c resistance of the microphone element coil



7.13

Figure 4-3.—Portable magnetic microphone.

with the value listed in the applicable manufacturer's instruction book. If the continuity and resistance checks disclose a faulty microphone element, switch, or cable, replace the affected component.

To replace a microphone element, unscrew the mouthpiece with the spanner wrench furnished with the microphone assembly. Do not attempt to unscrew the cylindrical metal band about the front of the microphone housing. This band is molded into the microphone housing and is not a retaining ring. Remove the element by inverting the housing so that it will drop out in the palm of the hand. If necessary, gently tap the housing in the palm of the hand until the element drops out. Then loosen the screws at the rear of the microphone element and remove the lugs or connecting leads from beneath the screwheads. Reassemble the new element in the reverse order of the foregoing procedure.

If it is necessary to replace the talk switch or connecting cable, remove the microphone element, as previously described, and reassemble the element in the new case.

CHARACTERISTICS

Microphones are rated according to their (1) frequency response, (2) impedance, and (3) sensitivity.

Shipboard announcing and intercommunicating systems are designed to produce maximum speech intelligibility under conditions of high background noise. To achieve this objective, the overall frequency response characteristic of the system is altered by cutting off the system response at some lower limit, such as 500 cycles, and by employing an emphasized frequency response characteristic, which rises with increasing frequency at a rate of approximately 6

decibels per octave. The output soundpressure is doubled each time the frequency is doubled for a constant level input to the system. The emphasized speech tends to sound thin and sometimes harsh, but when the masking (caused by background noise) is almost as high as the speech level, the speech appears to cut through the noise.

For good quality, a microphone must convert sound waves into electrical waves that have the same relative magnitude and frequency without introducing any new frequencies. The frequency range of the microphone must be at least as wide as the desired overall response limits of the system with which it is used.

Except in the case of the emphasized system in which it may be desirable for the microphone to have a rising frequency-response characteristic, the microphone response should be uniform or flat within its frequency range and free from sharp peaks or dips, such as those caused by mechanical resonances.

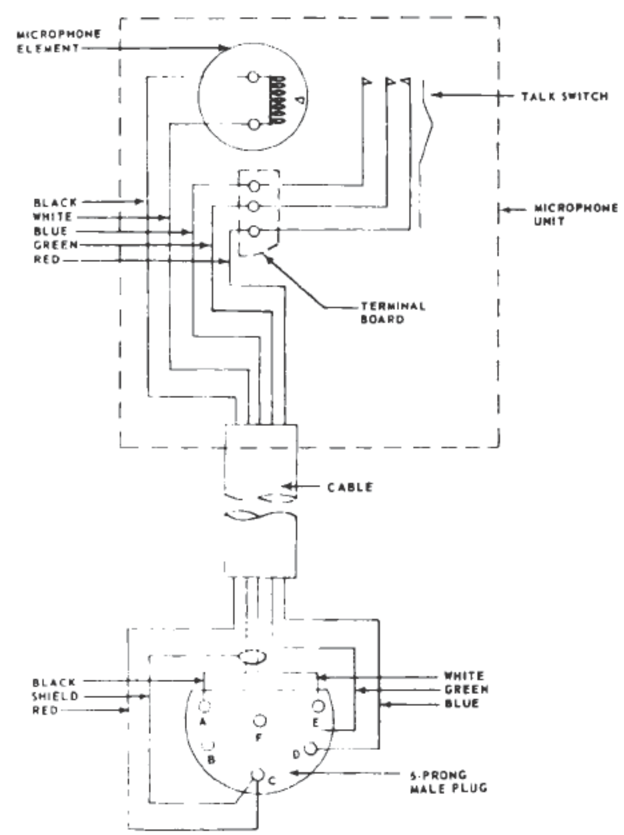


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Figure 4-4.—Wiring diagram of portable microphone.

Magnetic and dynamic microphones have impedances that range from 20 to 600 ohms. The impedance of a microphone is usually measured between its terminals at some arbitrary frequency within the useful range, such as 1000 cycles.

The impedance of magnetic and dynamic microphones varies with frequency in much the same manner as that of any coil or inductance—that is, the impedance rises with increasing frequency. The actual impedance of the microphone in shipboard applications is of importance only as it is related to the input load impedance into which the microphone is designed to operate. If the microphone is mismatched with the input impedance, the amplifier input is reduced and distortion occurs. All specifications and acceptability tests for naval microphones are based on the designed input load impedance.

The sensitivity or efficiency of a microphone is usually expressed in terms of the electrical power level that the microphone delivers to a terminating load, the impedance of which is equal to the rated impedance of the microphone, compared to the acoustical intensity level or pressure of the sound field being picked up.

Most systems rate the microphone in the electrical power level (in decibels below 1 mw) produced by an acoustical pressure of 1 dyne per square centimeter. For example, a microphone rated at -80 decibels means that for an input acoustical pressure of 1 dyne per square centimeter the electrical output is 80 decibels below 1 mw, or 10^{-8} mw. Other systems rate the microphone in terms of the voltage delivered to a specified terminating load impedance for an acoustical pressure input of 1 dyne per square centimeter.

It is important to have the sensitivity of the microphone as high as possible. High sensitivity means a high electrical power output level for a given input sound level. High microphone output levels require less gains in the amplifiers used with them and thus provide a greater margin over thermal noise, amplifier hum, and noise pickup in the line between the microphone and amplifier.

When a microphone must be used in a noisy location, an additional desirable characteristic is the ability of the microphone to favor sounds coming from a nearby source over random sounds coming from a relatively greater distance. Microphones of this type tend to cancel

out random sounds and to pick up only those sounds originating a short distance away. When talking into this type of microphone the lips must be held as close as possible to the diaphragm. Directional characteristics that favor sound coming from one direction only also aid a microphone in discriminating against background noise.

AUDIO AMPLIFIERS

The theory and principles of audio amplifiers are explained in chapter 6 of *Basic Electronics* and are not repeated in this chapter. However, a discussion is included of the performance characteristics that determine the ratio of audio amplifiers employed in naval announcing systems. These characteristics are (1) frequency range, (2) gain, (3) output power, (4) linearity, (5) use of volume compression, (6) noise, (7) impedance, and (8) output voltage regulation.

FREQUENCY RANGE

The frequency range of an amplifier specifies the frequency limits within which good amplifier performance can be expected. It is usually illustrated in the form of a frequency-response characteristic, which is a curve of amplifier gain versus frequency. The amplifier is the component of an announcing or sound system in which certain frequencies or bands of frequencies can be emphasized or suppressed most readily. By means of simple circuits within the amplifier, it is possible to provide low-frequency boost or attenuation, high-frequency boost or attenuation, emphasized-response characteristics, or to compensate for deficiencies in the microphones or loudspeakers.

GAIN

The gain can be considered as the difference (expressed in decibels) between the volume level of a signal at the input of the amplifier and the volume level of the same signal at the output of the amplifier. Amplifier gain is measured with the amplifier operating between definite values of impedance connected to the input and output terminals. The gain specified is obtained only when the amplifier is used with the correct terminating impedances.

The gain of an amplifier must be adequate to amplify the weakest usable input signal to full output power level. Amplifiers for naval use are designed with a certain amount of reserve gain to allow for variations in microphone and amplifier performance or to allow for a low-talking level at the microphone.

OUTPUT POWER

The output power rating of an amplifier is usually considered as the maximum single frequency power that the amplifier can deliver to a resistance load without overloading—that is, without excessive distortion. The output rating should apply for all frequencies within the usable range, especially where the maximum peaks of speech occur. A lower output rating is acceptable at very low or very high frequencies because the energy content of speech and of commonly used signals is low at these frequencies. Amplifiers designed for naval use generally have a reserve output power capacity at least 10 percent greater than that required for the installed system to provide for possible future expansion.

LINEARITY

An amplifier for ordinary use is assumed to be linear. In other words, the gain is the same when operating at low outputs as it is for higher outputs, giving a straight line when the input level is plotted against the output level. In certain cases nonlinear characteristics are incorporated in the amplifier design for special purposes.

VOLUME COMPRESSION

Volume compression is often employed to increase the intelligibility of speech in a communication system under conditions of high background noise. Volume compression is usually accomplished by introducing a circuit in the system amplifier, which varies the gain of the system as a function of the input level. For high-level input signals the system gain is reduced, and for low-level input signals the system gain is increased. This action tends to maintain constant output level and is similar to the action of the automatic volume control (AVC) circuit, except for the circuit time constant.

The variations in gain in volume compression are accomplished at a rapid rate sufficient to affect individual syllables of speech. In this way, the relatively weak consonant sounds, which account to a great extent for the speech intelligibility, are amplified and the strong vowel sounds, which do not contribute greatly to intelligibility, are reduced in intensity. The volume compression method also introduces a slight degree of unnaturalness to the speech quality, but is effective in improving intelligibility. With volume compression, only one-fourth of the acoustic power is required to provide the same speech intelligibility under noise that can be produced without volume compression. This gain reduces the size, weight, cost, and heat dissipation of the amplifier and loudspeaker equipment.

NOISE

The noise rating of an amplifier is the noise delivered by the amplifier to its load when no signal is present at the input and when the amplifier is protected from pickup from external sources. In other words, it is the inherent noise of the amplifier. It usually consists of thermal noise (in the high-gain amplifiers) and hum from the power supply.

IMPEDANCE

An amplifier is designed to operate with different values of impedance connected to its input and output terminals. The impedance connected to the input terminals should be as close to the design value as possible; otherwise the effective amplifier gain will be lowered and the frequency-response characteristic may be altered. The impedance connected to the output terminals of the amplifier should be as close as possible to the design value if maximum power output is to be obtained with a minimum of distortion.

The terms generally used concerning amplifier impedances are source, input, output, and load impedances.

The impedance connected to the amplifier input terminals or the impedance from which the amplifier operates is called the source, or generator impedance.

The impedance of the amplifier itself measured between the input terminals is called the internal input, or input impedance.

The impedance of the amplifier itself measured between the output terminals is called the internal output, or output impedance.

OUTPUT VOLTAGE REGULATION

The output voltage regulation is the variation in output voltage, which occurs when the rated load is disconnected from an amplifier that is operating at full rated output. This is an important characteristic for amplifiers, which are used on constant voltage systems in which substitute load resistors are not required as the number of connected loudspeakers is varied.

LOUDSPEAKERS

A loudspeaker is a device that converts electrical energy into equivalent sound energy and radiates this energy into the air in the form of sound waves. All loudspeakers consist essentially of a driving mechanism for changing electrical waves into equivalent mechanical vibrations that are transmitted to a diaphragm or other vibrating source. The vibrating source is coupled, either directly or by means of a horn, to the air and causes sound to be radiated. The loudspeakers in general use in the Navy are the (1) direct radiator type that radiates sound directly from a vibrating member into the air, and (2) horn type that consists of a driving unit combined with a horn to couple the unit to the air.

DRIVING MECHANISM

The driving mechanism changes the electrical variations into mechanical vibrations. The dynamic, or moving-coil, driving mechanism is the only basic type used in naval loudspeakers. The design of the dynamic loudspeaker is similar to that of the dynamic microphone (fig. 4-2). However, the principle of operation is the reverse of that of the dynamic microphone.

The moving coil, which is attached to the diaphragm, rests in a magnetic field. When a varying electric current flows through the coil, a force is exerted on the coil, causing it to move back and forth in the magnetic field. The consequent motion of the diaphragm causes the radiation of sound waves, which correspond to the variations in the electric current. The only variation in the dynamic-type loudspeaker is the

method employed for obtaining the magnetic field. These are the (1) electrodynamic and (2) permanent-magnet dynamic types of loudspeakers.

In the electrodynamic loudspeaker the magnetic field is established by passing a direct current through a field coil that is wound on an iron core. This type requires a source of filtered direct voltage and two additional conductors to carry the field current to the loudspeaker.

In the permanent-magnet dynamic loudspeaker the magnetic field is established by a permanent magnet. All loudspeakers used in naval applications are of the permanent-magnet dynamic type.

DIRECT RADIATOR LOUDSPEAKER

The direct radiator loudspeaker, sometimes called a cone loudspeaker, is the simplest form of sound radiator. In this type of loudspeaker (fig. 4-5) the diaphragm acts directly on the medium, which is air. Both sides of the diaphragm are open to the air so that sound is radiated in back as well as in front of the loudspeaker. At the instant the diaphragm is moving in an outward direction, a compression wave is produced by the front surface of the diaphragm, and a rarefaction wave is produced by the back surface of the diaphragm.

At low frequencies where the wavelength is large compared with the dimensions of the loudspeaker, the rarefaction wave from the back of the diaphragm meets the compression wave from the front of the diaphragm and neutralizes it because the waves are in opposite phase relation. Thus, low frequencies are not reproduced from this type of direct radiator.

At higher frequencies where the wavelength of the sound is small compared with the dimensions of the loudspeaker, the sound waves from the front of the diaphragm have time to travel an appreciable distance away from the loudspeaker (in terms of wavelength), and the phase of vibration of the diaphragm changes before the interfering wave from behind can traverse the distance around the diaphragm.

Therefore, a baffle is necessary to reproduce low frequencies from a direct radiator. The purpose of the baffle is to delay the meeting of the front and back waves by artificially increasing the distance of the soundwave path from the front to the back of the diaphragm. The simplest form of baffle is a flat board with a hole in the center to accommodate the loudspeaker. This type of baffle is effective down to a frequency, the wavelength of which is approximately four times the diameter of the baffle. If the loudspeaker is mounted in a wall or is completely enclosed, the baffle is called an infinite baffle. When a cabinet is used as a baffle, it is desirable to line the inside with a sound-absorbing material to minimize the effect of cabinet resonance produced by standing waves within the enclosure.

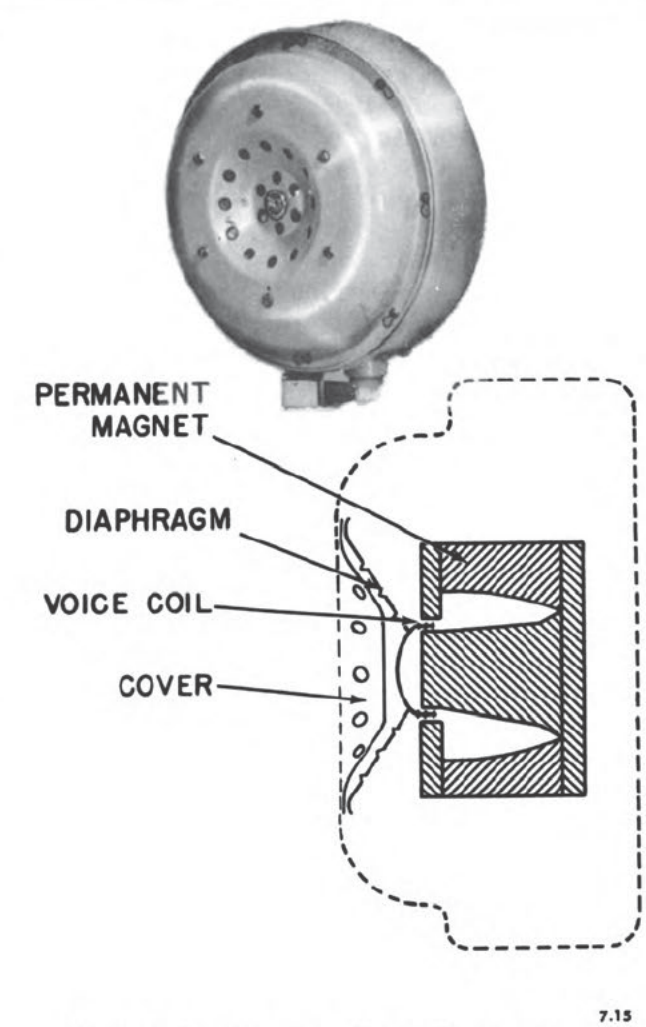


Figure 4-5.—Direct radiator loudspeaker.

HORN LOUDSPEAKERS

The use of the direct radiator loudspeaker is limited because of its low radiation efficiency. When it is necessary to produce high sound

intensities or to cover large areas with sound, the radiation efficiency of the loudspeaker must be increased to keep the size of the amplifier within reasonable limits. Horns with appropriate driver units provide a practical solution to the problem.

A horn loudspeaker may be considered as a device for coupling a relatively heavy vibrating surface at the horn throat to a relatively light medium (the air) at the mouth of the horn. The horn loudspeakers are (1) straight, (2) single-fold, and (3) double-fold types illustrated in figure 4-6.

For a horn to operate effectively, the mouth must be sufficiently large in comparison with the longest wavelength (lowest frequency) of sound to be transmitted. Low-frequency horns often are considered to be useful at frequencies above that for which the mouth diameter is about one-third of a wavelength. The performance of a horn loudspeaker near the low-frequency cutoff point depends to a great extent on the flare or shape of the horn. The function of the horn contour is to produce a smooth and continuous increase in cross-sectional area in progressing from the small throat to the large mouth. The shape most commonly employed is the exponential horn in which the diameter increases progressively by a fixed percentage

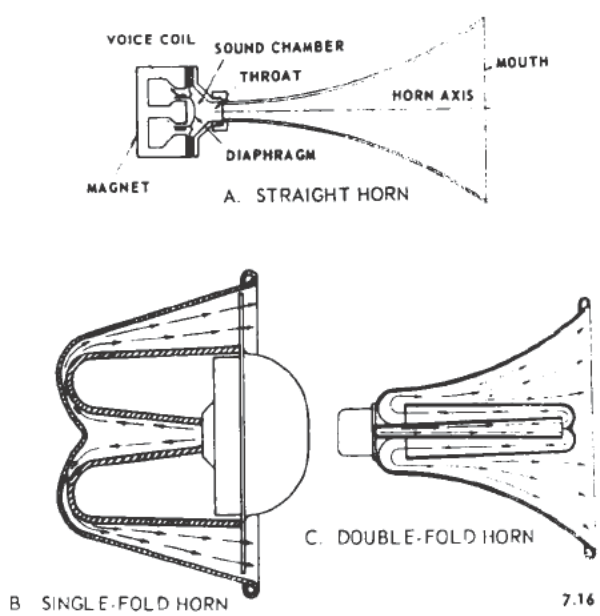


Figure 4-6.—Horn loudspeakers.

for each equal-distance increment along the horn axis.

For the horn to be of a practical size and shape, a folded-horn loudspeaker is employed (fig. 4-6, B, and C) in preference to a straight horn (fig. 4-6, A). There is a practical limit to the amount of power that can be handled by a conventional driver unit. When extremely high sound intensities must be produced, multiunit loudspeakers are employed in which the units are coupled to individual horn sections combined mechanically into a common loudspeaker assembly.

CONSTRUCTION

Representative dynamic horn loudspeakers are illustrated in figure 4-7. The respective wiring diagrams of these loudspeakers are illustrated in figure 4-8.

The double-fold horn loudspeaker (fig. 4-7, A) is designed to produce high acoustic levels with a minimum of power input. Volume adjustment is provided inside the loudspeaker by taps on the transformer. An additional volume adjustment of 0 to 24 db is provided by a control accessible from the outside of the loudspeaker (fig. 4-8, A). This loudspeaker is designed to operate directly from a 70-volt audio distribution line or from a 50-volt line when series protective resistors are used. The amplifiers used with these loudspeakers are designed to maintain a constant 70-volt output voltage independent of the loudspeaker load. Hence, dummy load or balancing resistors are not necessary when loudspeakers are disconnected from the line.

Each loudspeaker is equipped with a line matching transformer. The primary is tapped for operation on a 70-volt audio power line or on a 50-volt line when series protective resistors are used. The secondary is tapped for volume adjustments of (1) full power, 7.5 watts; (2) -6 db, 1.875 watts; (3) -12 db, 0.469 watts; and (4) -18 db, 0.117 watts.

The multiunit, straight-horn loudspeaker (fig. 4-7, B) is designed as a superpower, elliptical pattern, movable loudspeaker for audible communication between ships. Sound energy is radiated from the loudspeaker through a horizontal angle of 40 degrees and a vertical angle of 70 degrees. Under conditions of low ambient noise the range of the loudspeaker with

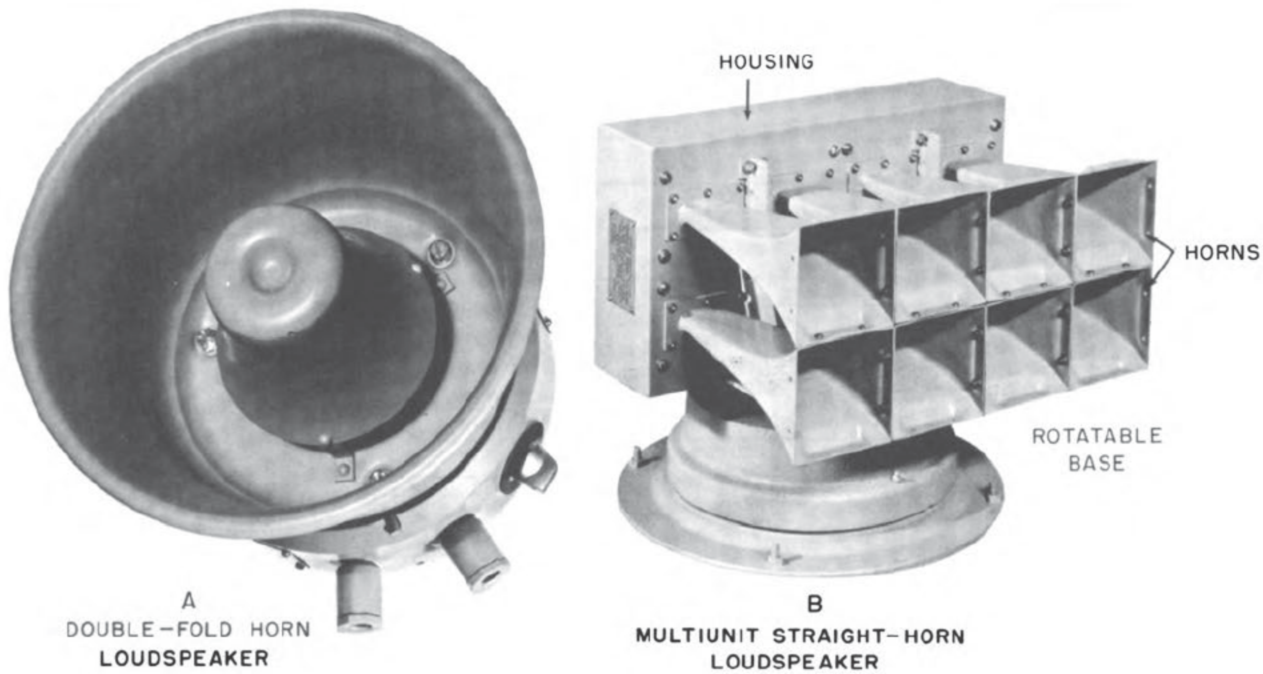


Figure 4-7.—Dynamic horn loudspeakers.

a maximum power applied is approximately one mile. The loudspeaker has an effective frequency range of from 500 to 6,000 cycles, and will safely handle a maximum power input of 250 watts.

The multiunit loudspeaker consists of a housing containing 16 driver units feeding into 8 horns. The assembly is mounted on a rotatable base, which enables the sound to be transmitted in a specific direction. The driver units are equipped with drainage slots, and holes in the bottom of the loudspeaker housing are provided to allow excess moisture to run out during wet weather. Blast valves (not shown) are provided to protect the driver-unit diaphragms from damage because of shock under battle conditions.

The base assembly consists of a ball-bearing race, which supports the horn and driver assembly. A length of THFA-4 cable enters at the bottom of the base, and the leads are connected to three brushes and slip rings. This arrangement enables the loudspeaker to be rotated horizontally through 360 degrees. A handwheel is provided for locking the loudspeaker in any desired position.

The 16 driver units are of the moving-coil type with permanent-magnet fields and a phenolic impregnated fabric diaphragm. A plastic throat provides efficient acoustic coupling between the diaphragms and the horn. In each assembly, two diaphragms face each other and radiate into a chamber, which feeds a horn. The diaphragms are phased so that their effect is additive. The driver units feeding each horn are connected in parallel (fig. 4-8, B). The loudspeaker is electrically divided into two groups of eight drivers each. The drivers feeding the top row of horns are in one circuit, and those feeding the bottom row of horns are in the other circuit. Each circuit consists of four pairs of drivers in series, resulting in a d-c resistance of 24 ohms per circuit.

An autotransformer assembly mounted in a separate case is provided with each multiunit straight-horn loudspeaker. The assembly consists of two autotransformers, each of which is connected to half of the driver units in the loudspeaker (fig. 4-8, B). The autotransformers are designed for use with amplifiers supplying either 50 volts or 70 volts to the line. The connections are made to a terminal block inside the case.

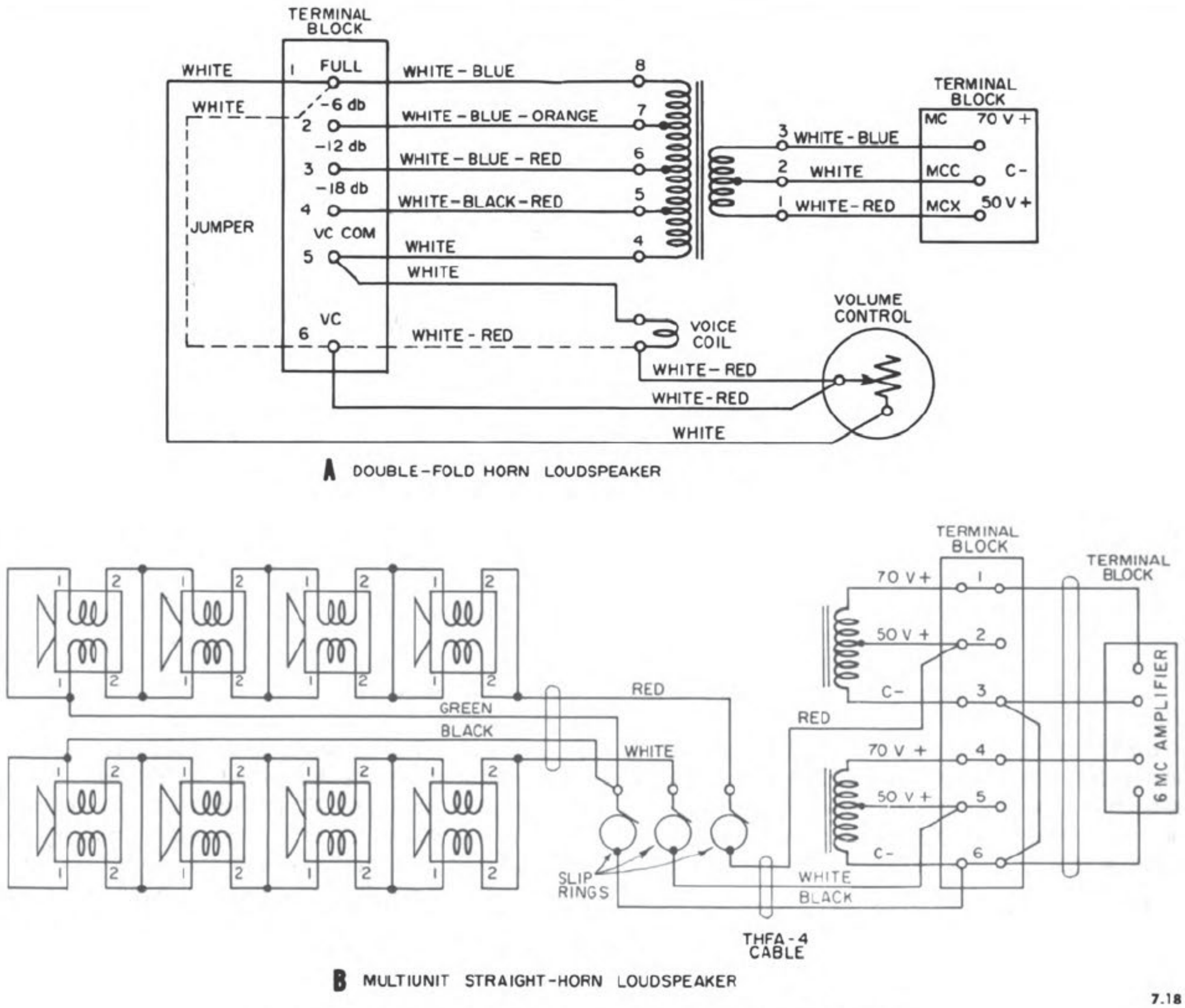


Figure 4-8.—Wiring diagrams of dynamic loudspeakers.

MAINTENANCE

The construction and operation of the double-fold horn loudspeaker (fig. 4-7, A) require very little preventive maintenance. However, salt encrustation is likely to occur when a loudspeaker is located where it is subjected to considerable spray. Under these conditions, the sound chamber and blast valve should be cleaned periodically. This is accomplished by removing the driver assembly and pouring a little warm water through the holes in the sound chamber onto the diaphragm, shaking, and then draining. Repeat this procedure several times.

If the loudspeaker should fail to operate, remove the horn and disconnect the ship's wiring from the terminals. Measure the d-c resistance between terminals MC and MCC (fig. 4-8, A). This resistance should be within ± 10 percent of the value specified in the applicable manufacturer's instruction book. If the resistance does not check, replace the wiring assembly.

If the resistance values at the terminals are normal, apply a 115-volt 60-cycle source in series with a 25-ohm resistance to terminals MC and MCC, and listen for sound from the loudspeaker. Turn the volume control knob to the maximum clockwise position. If a low-pitched sound is heard, the loudspeaker is probably functioning properly, and the ship's wiring to the loudspeaker is open or short circuited.

If no sound is heard, remove the voice coil terminal leads from the terminals and measure the resistance between the leads (fig. 4-8, A). If the resistance is not within ± 10 percent of the value specified in the manufacturer's instruction book, replace the wiring assembly.

If the resistance is normal, measure the resistance at the voice coil terminals while the leads are disconnected. If the resistance is within ± 10 percent of the specified value, apply a 115-volt 60-cycle source in series with an 80-ohm resistance to the voice coil leads for a short interval and listen for sound from the loudspeaker. If sound is heard, the wiring assembly is defective and should be replaced.

If no sound is heard or if the resistance is abnormal, measure the resistance of the voice coil at the driver terminals with the leads disconnected from the terminals. Check for a ground between the terminals and frame. If the resistance is normal, remove the blast valve (not shown) to the driver unit, and measure the resistance at the voice coil terminals with the leads removed. If the resistance is within ± 10 percent of the specified value, apply a 115-volt 60-cycle source in series with an 80-ohm resistance to the voice coil leads, and listen for sound from the loudspeaker. If sound is heard, replace the blast valve with a new one. If no sound is heard, replace the driver unit.

If there is low volume from the loudspeaker, turn the volume control knob to the maximum clockwise position. Remove the horn and check the position of the jumper on the terminal strip (fig. 4-8, A). Maximum and minimum volume is obtained with the jumper connected to terminal 1 (full) and terminal 4 (-18 db), respectively. Intermediate terminals give intermediate volume levels.

If repositioning the jumper does not give the desired volume with normal quality of reproduction, remove the horn and disconnect the ship's wiring from the terminals. Perform the tests described previously for failure of the loudspeaker to operate. If the trouble is not located after conducting these tests, replace the driver unit.

If the multiunit straight-horn loudspeaker (fig. 4-7, B) should fail to operate, remove the cover from the separately mounted transformer box. Disconnect the white lead from terminal 5 and the red lead from terminal 2 (fig. 4-8, B). Measure the resistance from the red lead to terminal 6 (black lead) and from the white lead to terminal 6. If the resistance readings agree with the values specified in the applicable manufacturer's instruction book, the trouble is probably in the autotransformers or ship's wiring. Disconnect the ship's wiring from the terminal strip, and measure the resistance between terminals 1 and 3, and terminals 4 and 6. If the readings are not in accordance with the specified values, replace the defective autotransformer.

If the resistances measured from the red lead to terminal 6 and from the white lead to terminal 6 do not agree with the specified values, remove the back of the loudspeaker case to expose the driver units. With the red and white leads disconnected in the transformer case, measure the resistance between terminals 1 and 2 of each pair of driver units. Note that each driver pair is connected in parallel. If the resistances of all the driver pairs agree with the specified values, the trouble is in the wiring or slip rings inside the base.

If the resistance of a pair of drivers is above or below the specified value, disconnect the wiring from the defective pair of driver units and measure the resistance of both drivers. If one or both drivers are open circuited or indicate a high resistance, replace the faulty driver with a new one.

In the event of low volume from the loudspeaker, be certain that full power is applied to it from the amplifiers by observing the amplifier output meters. If the volume is about half of normal, it is possible that only half of the driver units is energized. If the trouble is not located, perform the tests described previously for failure of the loudspeaker to operate.

If the resistances measured in these tests are normal, reconnect all wiring inside the loudspeaker and disconnect the red, white, and black leads from terminals 2, 5, and 6, respectively, in the transformer box which feeds the speaker (fig. 4-8, B). Connect a 115-volt 60-cycle source in series with an 80-ohm resistance to the red and white leads, and listen for a hum in each of the eight horns of the loudspeakers. If the hum is weaker or absent in one or more horns, remove the driver units that feed the horns with the weak output, and replace them with new units.

More detailed information concerning the repair and replacement of loudspeaker components is contained in the manufacturer's instruction book furnished with the equipment installed in your ship.

CHARACTERISTICS

In the majority of cases the frequency response of the loudspeaker is the limiting factor in the overall response of a sound system. For direct radiators the low frequency response is influenced by the (1) baffle or enclosure, (2) diameter of the cone, (3) ability of the cone and voice coil to execute large amplitudes of vibration, and (4) strength of the magnetic field in the air gap. This high-frequency response is limited by the mass of the voice coil and diaphragm.

For horn loudspeakers the low frequency response is influenced principally by the (1) basic horn formula employed, (2) flare, and (3) mouth dimensions. The high frequency response is limited by the (1) mass of the voice coil and the diaphragm, (2) phase effects caused by differences in path lengths due to bends, and (3) impedance irregularities caused by sudden changes in cross-sectional areas at folds or joints in the horn. Vibrations of the horn walls must be sufficiently damped to avoid introducing irregularities into the response as well as transient effects.

The directivity of a loudspeaker is an important factor in determining the efficiency of the sound radiation over the listening area. All practical forms of sound radiators exhibit some directional effects. If a radiator is placed in free space where the results are not affected by interfering reflections, the sound pressure at a given distance is not the same in all directions. The directivity of a loudspeaker is a function of both frequency and the size of the horn mouth of the loudspeaker. Thus, a loudspeaker becomes more directional with increasing frequency because of the shorter wavelength, and a direct radiator or horn mouth of large size is more directional than one of smaller size. These factors of frequency and size are interrelated in that the size becomes a factor relative to the wavelength of the sound being transmitted. Thus, the directional pattern of a small loudspeaker transmitting a high-frequency signal (short wavelength) is similar to that of a large loudspeaker transmitting a low-frequency signal (long wavelength). In general, a horn loudspeaker of a given mouth diameter is more directional than a direct radiator of the same diameter, particularly at the lower frequencies.

The directivity of a horn loudspeaker also depends on the rate of flare—that is, the directivity increases as the flare is made more gradual (longer horn). If a rectangular horn having a long narrow mouth (in terms of wavelength) is mounted with the long dimension of the mouth vertical, the radiation in the horizontal plane corresponds to that of a small radiator with a broad distribution pattern. The radiation in the vertical plane acts as a large radiator with a relatively narrow beam. In other words, the horn is made relatively much less directional in the horizontal plane than in the vertical plane. It is obvious that the reverse is true if the horn is turned so that the long dimension of the mouth is horizontal. Thus the sound energy is flattened out in a plane at right angles to the long dimension of the loudspeaker mouth. This principle is used to obtain the required directional characteristics for efficient high-intensity reproduction on the flight decks of aircraft carriers.

The load-carrying capacity of a loudspeaker is usually expressed in terms of the maximum electrical power that would be applied to it. This power is limited by heating, mechanical strength, and the production of nonlinear distortion, which is caused by excessive diaphragm amplitudes or excessive acoustical pressures in the sound passages. Excessive power causes the diaphragm to strike portions of the magnet or supporting frame and may produce buzzing or rattling.

The loudness of the sound obtainable from a loudspeaker at any particular listening point is not a factor of load-carrying capacity alone. Other important factors are the efficiency and the amount that the sound is spread out. The definition of absolute efficiency of a loudspeaker is not subject to simple practical interpretation. However, for specification purposes and for checking the performance of loudspeakers, a specified voltage is applied to the input terminals, and the output sound pressure is measured at a given distance from the loudspeaker on the loudspeaker axis, using various test frequency signals. These measurements are combined

with off-axis, sound-pressure measurements to evaluate the relative loudspeaker efficiency.

When satisfactory frequency in a loudspeaker is limited to a small angle about the axis, the absolute efficiency at high frequencies is considerably lower than at low frequencies. The use of diffusing arrangements with these loudspeakers to spread out the high frequencies usually results in spreading out the small amounts of available high-frequency energy to such an extent that the response is unsatisfactory at all locations.

The impedance of a loudspeaker is usually measured between the voice coil terminals at some average frequency, such as 1000 cycles, in the usable range. This impedance varies with the frequency, rising with increasing frequency. The usual value of voice coil impedance varies from 3 to 15 ohms.

In shipboard announcing and public-address systems, a matching transformer is built into each loudspeaker to transform the low voice coil impedance to a higher value suitable for connection to loudspeaker distribution lines. Because loudspeakers in a system are connected and operated in parallel, the combined impedance of a large number of low-impedance voice coils without matching transformers would be so low compared with the resistance of the connecting cables that an appreciable portion of the amplifier output power would be dissipated in the cable. Thus, matching transformers are provided to reduce this loss. These transformers have several taps in order to vary the loudspeaker impedance. Changing the loudspeaker impedance changes the power absorbed by the loudspeaker from the lines, and thus provides a means of varying the loudness of the loudspeaker.

QUIZ

1. What is the function of a microphone?
2. Name the two types of microphones most commonly used in naval announcing systems.
3. Name the principal components that comprise the driving mechanism of a magnetic microphone.
4. Name the principal components that comprise the driving mechanism of a dynamic microphone.
5. If an intercommunication system should fail to operate from a particular microphone station, what two tests should be performed after determining that the fault is in the portable microphone assembly?
6. Name the three factors that determine the rating of microphones.
7. How is the overall frequency-response characteristic of shipboard announcing and intercommunicating systems altered to achieve maximum speech intelligibility under conditions of high background noise?
8. In what way is the impedance of a microphone important?
9. Why is it important to have the sensitivity of the microphone as high as possible?
10. What does the frequency range of an audio amplifier specify?
11. How is the frequency range of an amplifier usually illustrated?
12. What is usually considered as the gain of an amplifier?
13. How must an amplifier be operated to obtain the gain specified?
14. What is meant by the output power rating of an amplifier?
15. What is an amplifier assumed to be when the gain is the same when operating at low outputs as it is for higher outputs and gives a straight line when the input level is plotted against the output level?
16. Why is volume compression employed in a communication system?
17. How is volume compression accomplished?
18. What is the effect on the amplifier gain and the frequency-response characteristic if the impedance connected to the input terminals is not as close as possible to the design value?
19. What is the effect on the maximum power output if the impedance connected to the output terminals of the amplifier is not as close as possible to the design value?
20. What is the function of a loudspeaker?
21. Name the two types of loudspeakers used in the Navy.

22. What is the basic type of driving mechanism used in Navy loudspeakers?
23. How does the operation of the dynamic loudspeaker driving mechanism differ from that of the dynamic microphone?
24. Why is it desirable in the direct radiator loudspeaker to increase the length of the sound path from the back to the front of the diaphragm?
25. What means is provided in the direct radiator loudspeaker to increase the distance of the sound path from the front to the back of the diaphragm?
26. Name the two types of horns employed in horn loudspeakers.
27. How are extremely high sound intensities produced?
28. What is the limiting factor in the overall response in the majority of sound systems?
29. What two factors influence the directivity of a horn loudspeaker?
30. How is the directivity related to the frequency for a given loudspeaker?
31. Name the three factors that limit the capacity of a loudspeaker.
32. How are the voice coils of loudspeakers matched to audio transmission lines?

CHAPTER 5
ANNOUNCING AND INTERCOMMUNICATING SYSTEMS

Shipboard announcing and intercommunicating systems, circuits 1MC through 34MC, serve the general purpose of transmitting orders and information between stations within the ship by amplified voice communication. This function is accomplished by either (1) a central amplifier system, or (2) an intercommunicating system. A central amplifier system is employed when it is desired to broadcast orders or information simultaneously to a number of stations. An intercommunicating system is employed when it is desired to provide two-way transmission of orders or information.

Each announcing and intercommunicating system installed aboard ship is assigned an I.C. circuit designation in the MC series. The Chief of Naval Operations authorizes these MC circuits for each class of vessel, based on size, complement, function, and operational employment. Authorized I.C. announcing circuits are listed in Table 5-1, according to importance and readiness. These systems, however, are not all installed in any one ship. A more detailed description of these circuits is contained in the General Specifications for Ships of the U.S. Navy, S65-0 and S65-2, dated 1 May 1958.

CENTRAL AMPLIFIER ANNOUNCING SYSTEM

The central amplifier announcing system is designed to furnish amplified voice communications and alarm signals to the various loud speaker groups aboard ship. The system provides for transmitting the spoken word or signal at any one of several stations, amplifying this signal from a number of loudspeakers.

A representative central amplifier announcing system installed in a cruiser is illustrated by the schematic diagram in figure 5-1. The system consists of audio amplifier equipment to provide circuit 1MC functions for general announcing and circuit 6MC functions for intership announcing.

The components employed in this equipment include: (1) alarm contact makers, (2) microphone control stations, (3) audio amplifier cabinet, (4) circuit 1MC loudspeakers, and (5) circuit 6MC loudspeakers. Power for operating the equipment is obtained from the ship's single-phase 115-volt power supply.

ALARM CONTACT MAKERS

Alarm contact makers are located throughout the ship. The closure of an alarm contact maker will sound any one of four alarm signals over all circuit 1MC loudspeakers. Alarm signals are not transmitted over circuit 6MC. The alarm signals in the order of their priority are: (1) collision, (2) chemical attack, (3) general, and (4) sonar. The order of priority is controlled automatically by relays in the audio amplifier cabinet. Any alarm takes priority over voice announcements.

If an alarm is being sounded and a higher priority alarm contact maker is closed, relays in the audio amplifier cabinet operate to cut off the alarm signal being sounded and cause the higher priority alarm to be sounded instead. Conversely, the closure of a low priority alarm contact maker has no effect on a high priority alarm that is being sounded. The oscillator operates to generate the alarm signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker). Release of the alarm contact maker causes the equipment to be returned to STANDBY after sounding the alarm. The visual alarm circuit is closed continuously during a chemical attack alarm, and intermittently during a general alarm.

MICROPHONE CONTROL STATIONS

Four microphone control stations are located at various points throughout the ship. The circuit 1MC-6MC microphone control station can select any one or more of the four 1MC loudspeaker groups or the circuit 6MC loudspeakers. The

Table 5-1.—Shipboard Announcing Systems.

Circuit	System	*Importance	Readiness
1MC	General	SV	1
2MC	Engineers'	SV	1
3MC	Aviators'	SV	1
4MC	Damage Control	SV	2
5MC	Flight Deck	SV	2
6MC	Intership	SV	2
7MC	Submarine Control	V	1
8MC	Signal Bridge	SV	2
10MC	Dock Control	SV	1
11-16MC	Turret	SV	3
8MC	Bridge	NV	2
19MC	Ready Room	SV	2
20MC	Combat Information	SV	1
21MC	Captain's Command	SV	1
22MC	Radio Room	NV	1
23MC	Distribution Control	SV	1
24MC	Flag Officers Command	SV	1
25MC	Wardroom	NV	4
26MC	Machinery Operation Control	SV	1
27MC	Sonar Control	SV	1
28MC	Squadron	NV	4
29MC	Sonar Information	SV	2
30MC	Bomb Shop	SV	2
31MC	Escape Hatch	SV	2
32MC	Missile Control	SV	3
33MC	Gunnery Control	SV	3
34MC	Lifeboat	SV	1

* V vital
SV semi-vital
NV non-vital

other microphone control stations are wired to permit the selection of circuit 1MC loudspeaker groups only. The operation of circuit 1MC from any microphone control station has priority over circuit 6MC operation. Microphone control stations on circuit 1MC do not have priority over each other, however, the bridge station does have priority over all others.

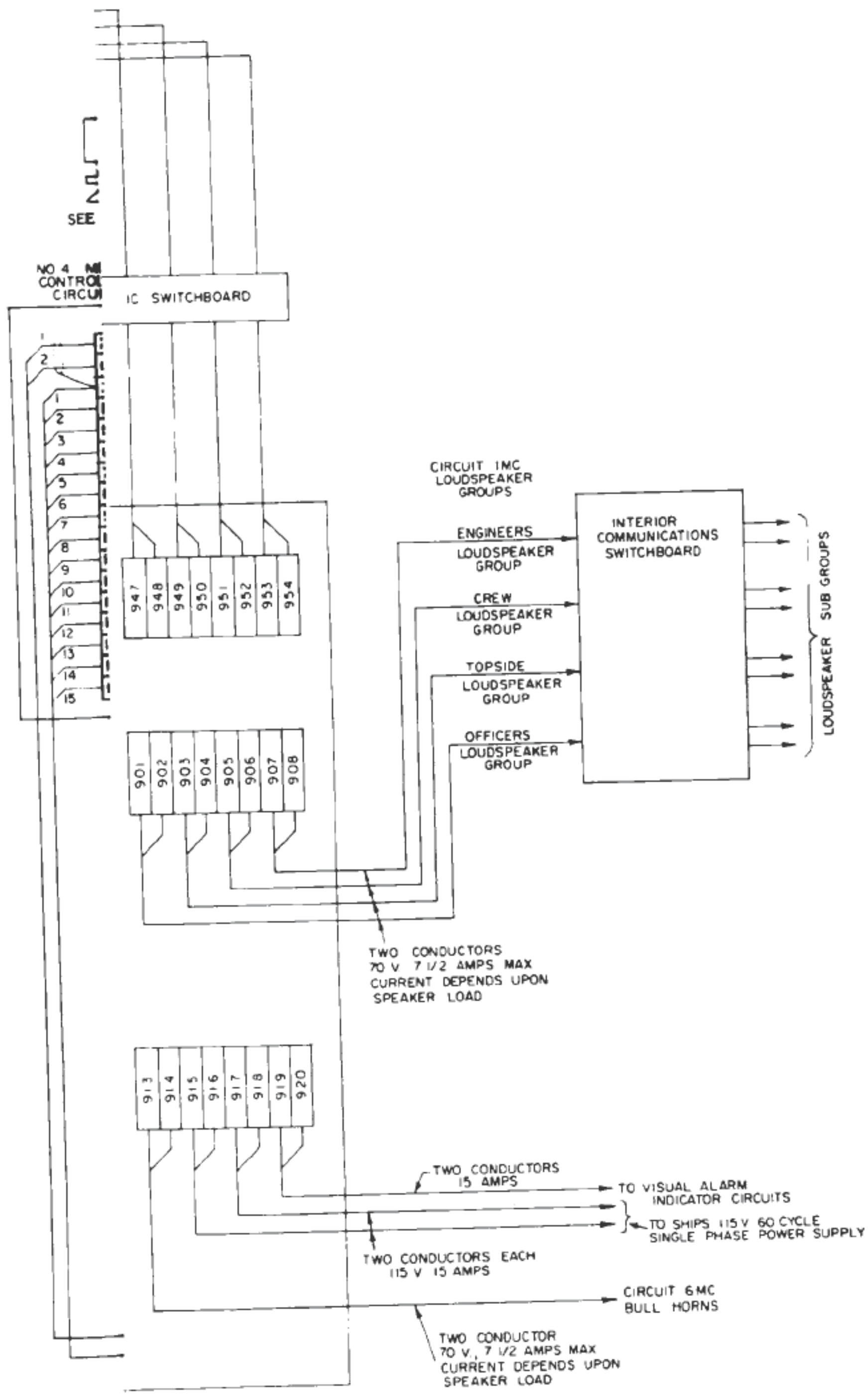
When the press-to-talk switch on the microphone of any microphone control station is operated for general voice announcements (fig. 5-2), all loudspeakers selected at this control station (except the loudspeaker in the immediate area of the control station in use) are connected to the equipment and reproduce the message spoken into the microphone. It is possible for the 1MC-6MC microphone control station to transmit over circuit 6MC loudspeakers at the same time that a circuit 1MC microphone control station is transmitting over a circuit 1MC loudspeaker group.

LOUDSPEAKER GROUPS

The loudspeakers associated with circuit 1MC operation are divided into four groups designated (1) officers, (2) topside, (3) crew, and (4) engineers. There is only one circuit 6MC loudspeaker group.

AUDIO AMPLIFIER CABINET

The control circuits for circuit 1MC and circuit 6MC are contained in the audio amplifier


SEE
NO 4
CONTRO
CIRCU
IC SWITCHBOARD
CIRCUIT 1MC LOUDSPEAKER GROUPS
ENGINEERS LOUDSPEAKER GROUP
CREW LOUDSPEAKER GROUP
TOPSIDE LOUDSPEAKER GROUP
OFFICERS LOUDSPEAKER GROUP
INTERIOR COMMUNICATIONS SWITCHBOARD
LOUDSPEAKER SUB GROUPS
947 948 949 950 951 952 953 954
901 902 903 904 905 906 907 908
913 914 915 916 917 918 919 920
TWO CONDUCTORS 70 V 7 1/2 AMPS MAX CURRENT DEPENDS UPON SPEAKER LOAD
TWO CONDUCTORS 15 AMPS
TO VISUAL ALARM INDICATOR CIRCUITS
TO SHIPS 115 V 60 CYCLE SINGLE PHASE POWER SUPPLY
TWO CONDUCTORS EACH 115 V 15 AMPS
CIRCUIT 6MC BULL HORNS
TWO CONDUCTOR 70 V, 7 1/2 AMPS MAX CURRENT DEPENDS UPON SPEAKER LOAD

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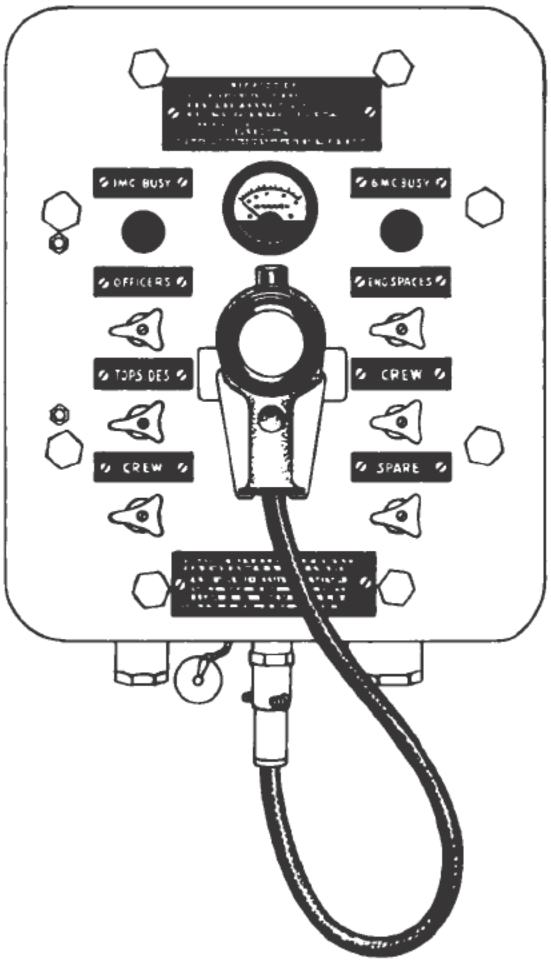

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Figure 5-2.—Microphone control station.

cabinet (fig. 5-3). In addition to the various relays, indicator lamps, fuses, transfer switches, and test switches, the cabinet contains two oscillator assemblies, two preamplifier assemblies, and two power amplifier assemblies.

The oscillators, one of which is a spare, are used to generate the alarm signals. The preamplifiers are used to increase the microphone output on voice signals to a level sufficiently high to drive the power amplifiers. The power amplifiers are used to increase the level of the alarm signals from one of the oscillators and the voice signals from one of the preamplifiers for reproduction by the loudspeakers.

Two identical amplifier channels are provided to permit the operation of the 1MC and 6MC circuits independently on the two channels (fig. 5-4). Each channel includes a preamplifier and a power amplifier. Channel selection is accomplished by means of the amplifier channel selector switch on the audio amplifier cabinet.

Normal operation of the system is obtained with the amplifier channel selector switch set at 1MC on A and 6MC on B. When the switch is set at 1MC-6MC on A, channel B is isolated for trouble shooting and repair, and the announcements and alarm signals are transmitted on channel A. Conversely, when the switch is set at 1MC-6MC on B, channel A is isolated and all transmission is over channel B.

Preamplifier

The preamplifier (fig. 5-5) consists of a power supply, V13 and V14, three parallel-connected voltage amplifier stages V1-V2, V3-V4, and V9-V10, a push-pull parallel-connected power amplifier stage, V5-V6, a limited circuit, V11 and V12, and a compressor circuit, V7 and V8.

The input to the power supply transformer, T3, is supplied through terminals C and D of the multiconductor plug P1. The high voltage winding of T3 is connected to the parallel-connected rectifier tubes V13 and V14 for full-wave rectification. The two-section capacitor input filter, consisting of capacitors C15 through C20 and chokes L1 and L2, is used for smoothing the d-c output. The power supply furnishes positive plate and screen voltages for all tubes except V7 and V8 in the compressor circuits, and negative bias voltage through the compressor ON-OFF switch, S1, to V7 and V8 in the compressor circuit. The filament winding of T3 supplies the filament power for all tubes. Potentiometer R47 in the secondary of T3 is used for hum control.

Voice announcements from the microphone control stations are fed to the input transformer T1 through pins N and P of plug P1. The secondary of T1 is connected through the gain control potentiometer R16 to the control grids of the first stage voltage amplifier tubes V1 and V2 which are operated in parallel. Tubes V1 and V2 amplify the signal voltage and are resistance-coupled through R7, C4, and R10 to the control grids of the second stage voltage amplifier tubes V3 and V4 which are operated in parallel.

The output of V3 and V4 is resistance-coupled through R13, C7, and R15 to the push-pull parallel power amplifier, V5 and V6. The control grids

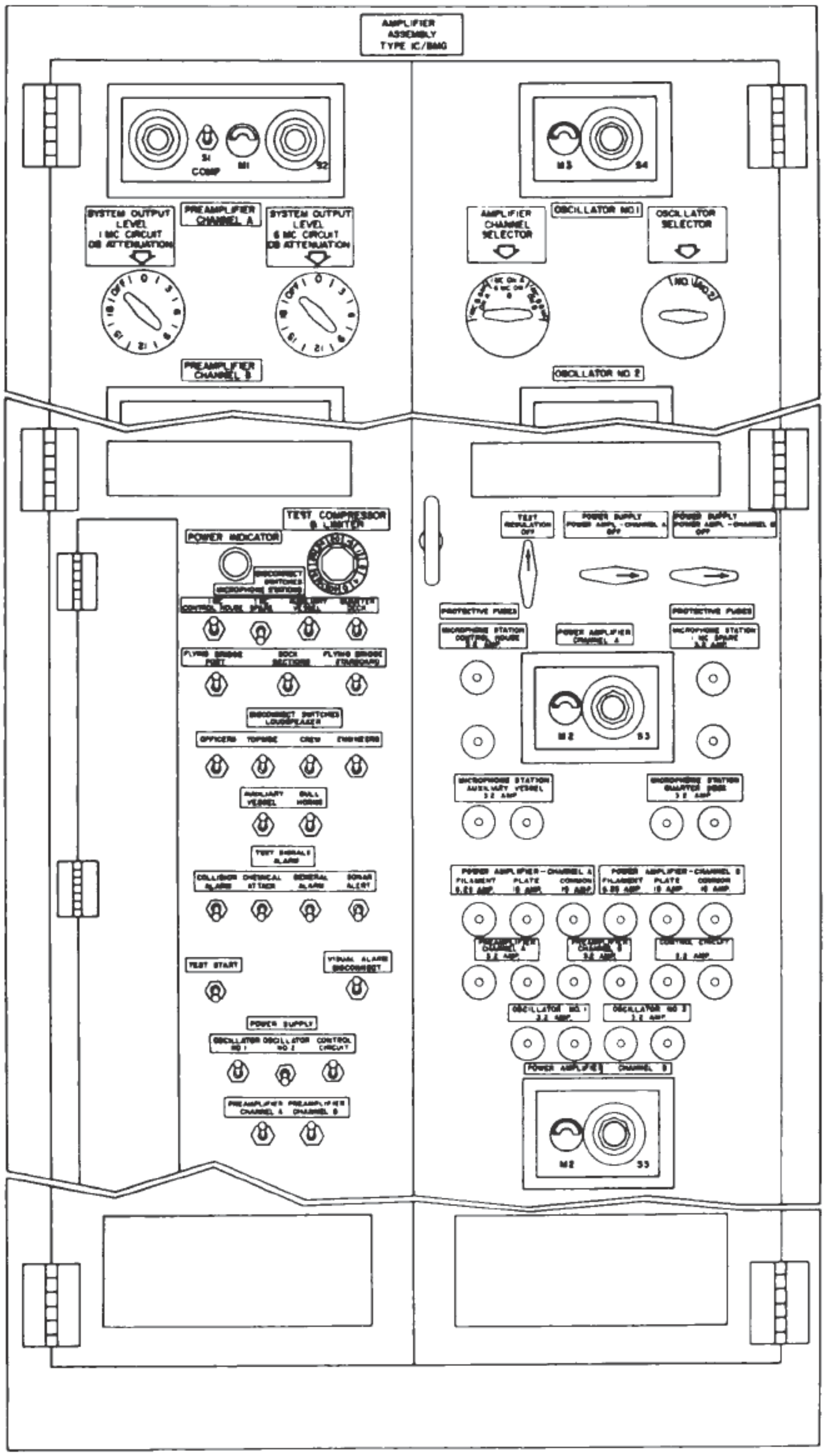


Figure 5-3.—Audio amplifier cabinet.

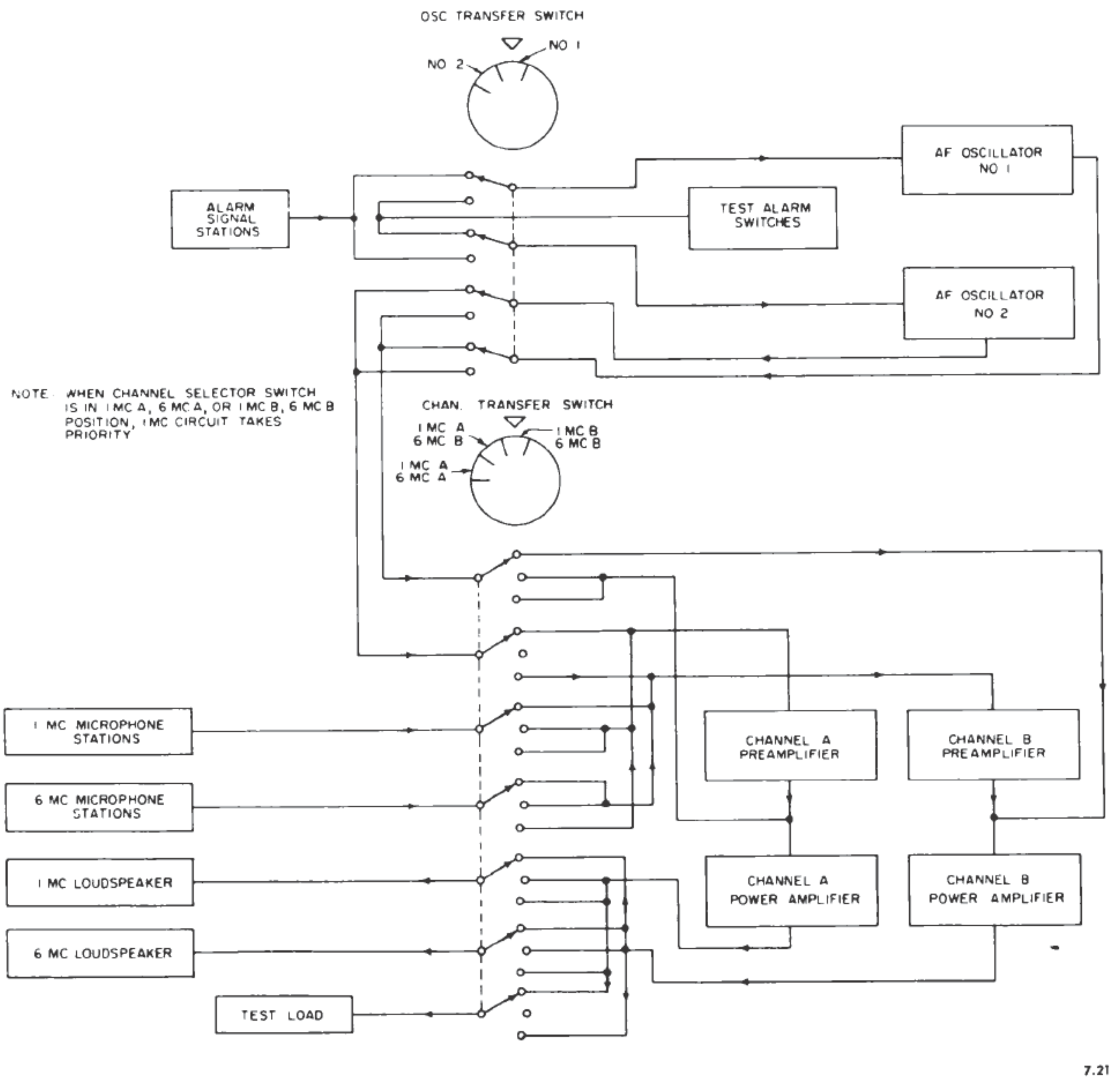


Figure 5-4.—Block diagram of circuit 1MC and circuit 6MC announcing system.

(pins 2) of V5A and V6A are connected directly to the top of potentiometer R15. The control grids (pins 7) of V5B and V6B are connected via C8 to the junction of R19 and R20, and receive a signal voltage which is equal to, and 180 degrees out-of-phase with that applied to pin 2. This action develops the normal input signal for push-pull operation.

The COMPRESSOR circuit provides greater amplifier gain with low-level signals than with high-level signals. When the compressor switch, S1, is in the ON position, the bias of V1 and V2 is reduced, resulting in a 14 db maximum increase in amplifier gain for low-level input signals. The LIMITER circuit provides for a rapid reduction in amplifier gain when the amplitude of the input

signal would overload the amplifier and cause distortion.

The compressor-limiter circuit consists of twin triodes, V11 and V12, operating as a phase-inverter (V11A and V12A) and limiter (V11B and V12B). The twin triodes, V9 and V10, function as push-pull voltage amplifiers, and the twin diodes, V7 and V8, act as a full-wave signal rectifier under certain signal conditions.

The signal voltage for the compressor circuit is taken from the input signal applied to the grids (pin 2) of the power amplifier, V5A and V6A, across potentiometer R15. This signal is applied to the grids (pin 2) of the split-load phase-inverter section, V11A and V12A, through series resistor R37, C14, and C13. The phase inverter produces two unamplified output voltages which are equal in amplitude but 180 degrees out-of-phase with each other. One output voltage is resistance-coupled from the plates (pin 1) of V11A and V12A through C11 and R31 to the control grids (pin 2) of voltage amplifier, V9A and V10A. The other output voltage is resistance-coupled from the cathodes (pin 3) of V11A and V12A through C12 and R32 to the control grids (pin 7) of V9B and V10B. The amplifier output voltages from the plates (pins 1 and 6) of V9 and V10 are resistance-coupled to the cathodes (pins 1 and 5) of the full-wave rectifiers V7 and V8 through C9 and R25, and C10 and R26 respectively.

The plates (pins 2 and 7) of V7 and V8 are connected in parallel and returned to a negative bias through R42. If the signal voltage applied to the cathodes of V7 and V8 is greater (more negative) than the bias voltage, applied to the plates, the diode sections of V7 and V8 will conduct alternately and a rise in the negative voltage existing between the plates (V7 and V8) and ground will result. (C21 is a ripple filter for the rectified output voltage.) The voltage thus produced is applied to the grids (pins 1 and 7) of V1 and V2 to control the gain of this amplifier stage. An increase in the negative bias voltage will result in a decrease in the gain of this stage.

This bias voltage is also coupled to the control grids (pin 7) of the limiter section, V11B and V12B. The effective plate-cathode resistance of V11B and V12B increases as the negative bias increases, making V11B and V12B behave like a variable resistance, the value of which is controlled by the magnitude of the bias voltage. The bias voltage in turn is controlled by the amplitude of the input signal to the compressor circuit.

The limiter section, V11B and V12B, is connected so that its effective plate-cathode resistance appears between the input grid (pin 2) of the inverter section, V11A and V12A, and ground. It (limiter section) serves as one leg of a voltage divider composed of R15 and R37 and the plate resistance of V11B and V12B to control the input voltage to the compressor circuit. Thus, the signal input to the control grids (pin 2) of the inverter section V11A and V12A, and results in limiting the audio output voltage of the two-stage voltage amplifier V1-V2 and V3-V4.

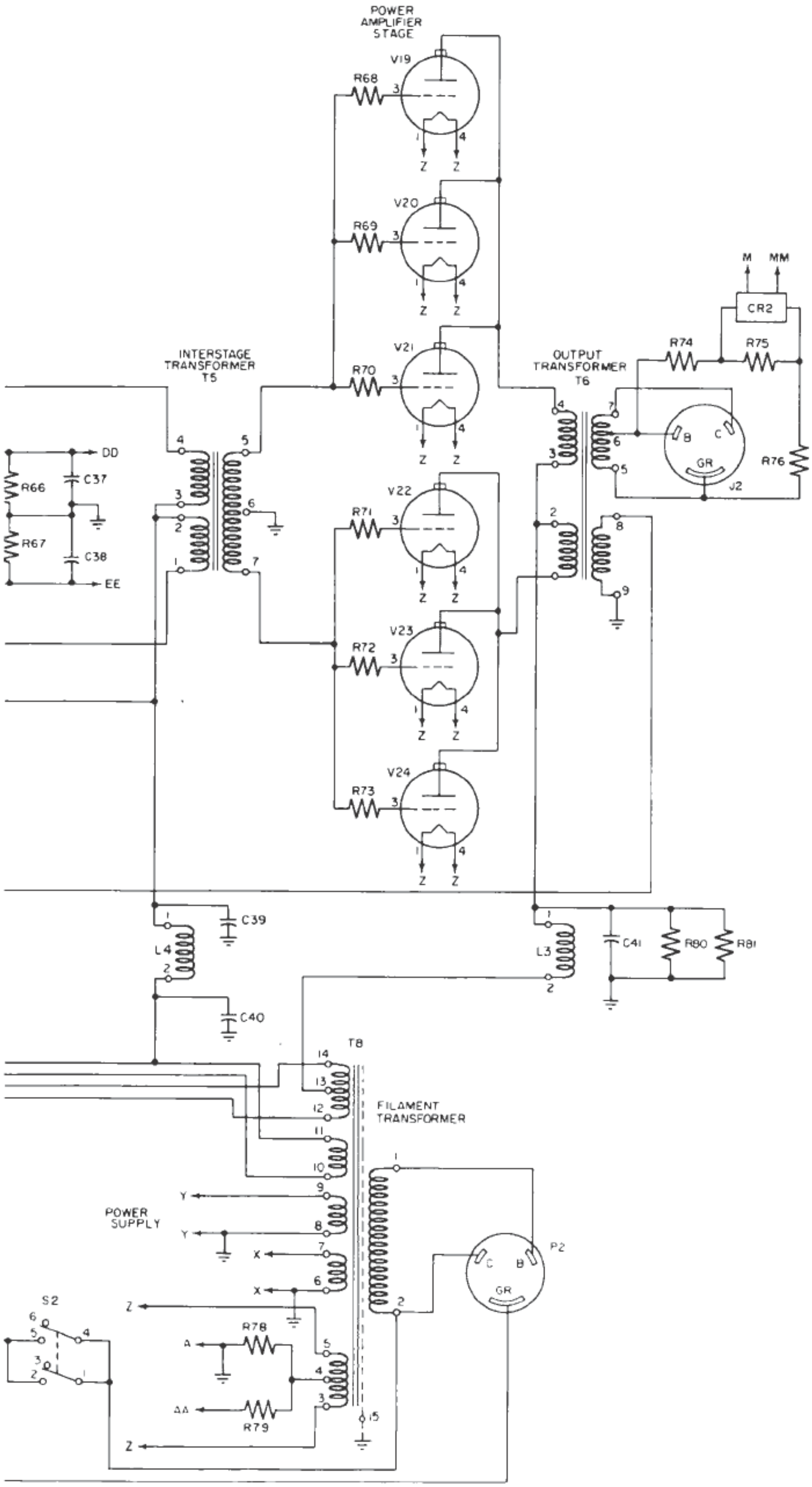
When the compressor switch, S1, is in the OFF position, a large negative operating bias voltage is connected to the bias line via R42 and the output voltage of the voltage amplifier is proportional to the input voltage up to the rated input that delivers full power. Above this point the limiter circuit causes the output voltage of the preamplifier to level off at its maximum rating.

When the compressor switch, S1, is in the ON position, a smaller negative operating bias voltage is connected to the bias line and the amplifier gain increases because the bias on the grids (pin 7) of the first stage voltage amplifier, V1 and V2, has been made less negative. The diodes, V7 and V8, conduct at a lower signal level and thus take control of the preamplifier gain at a lower signal level. The net result of this action causes the preamplifier to have a higher gain for low-level signals than for high-level signals, tending to maintain the same output signal level irrespective of the amplitude of the input signal. When the maximum rating of the output voltage is reached, the limiter causes the signal amplitude to level off. The audio output from T2 is fed to pins V and X of plug P1 for transmission to the power amplifier associated with the preamplifier in the operating channel.

Normal operation of the preamplifier can be checked by measuring the overall output and plate current of each stage by the meter, M1, and meter switch, S2. The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading of Odb ± 2db.

Power Amplifier

The power amplifier (fig. 5-6) consists of a voltage amplifier stage (V15A-V16A), a phase



POWER AMPLIFIER STAGE
V19
V20
V21
V22
V23
V24
R68
R69
R70
R71
R72
R73
INTERSTAGE TRANSFORMER T5
OUTPUT TRANSFORMER T6
R66
R67
C37
C38
DD
EE
M
MM
CR2
R74
R75
R76
J2
C39
L4
C40
L3
C41
R80
R81
T8
FILAMENT TRANSFORMER
POWER SUPPLY
P2
S2
R78
R79

inverter (V15B-V16B) stage, two driver stages (V17-V18) and a final power amplifier stage, V19, V20, V21, V22, V23 and V24. Two tubes (not sections) operate in parallel for every stage except the final stage which has two groups of three triodes in parallel and the two groups in push-pull. The parallel connection of the triodes permits circuit operation in the event of failure or removal of one tube per stage (two tubes in the final stage).

The power to operate the power amplifier is supplied through the 3-conductor polarized plug, P2, directly to the filament transformer, T8, and through switch, S2, to the plate power transformer, T7. The time-delay relay, K43 or K46, (not shown) external to the amplifier chassis prevents the application of power to T7 until approximately 30 seconds after filament power has been applied. The five secondary windings of T8 supply the filament power to all tubes.

The plates of the power output tubes, V19 through V24, are supplied +1365 volts via V27 and V28 connected for full-wave rectification across the high-voltage secondary winding of T7. The rectified voltage appears between ground and terminal 13 of T8, and is fed to the plates of the output tubes, V19 through V24, through a choke-input filter comprising inductor L3 and capacitor C41.

The plate power for the driver (V17A and B and V18A and B) and voltage amplifier and inverter (V15A and B and V16A and B) stages of the power amplifier is supplied by the two rectifier tubes, V25 and V26, also connected for full-wave rectification across 365-volt taps on the secondary of T7. The rectified voltage appears between ground and terminal 11 of T8, and is fed to the plates of the driver tubes, V17A and B, and V18A and B, through a capacitor-input filter comprising inductor L4 and capacitors C39 and C40.

Amplified voice signals from the associated preamplifier (fig. 5-5) or alarm signals from one of the oscillators are fed to the power amplifier through the 3-conductor jack, J1, to the primary of the input transformer, T4. The secondary of T4 is coupled to the voltage amplifier stage comprising tubes V15A and V16A through the gain control potentiometer, R52.

The driver stages comprise tubes V17A and B, and V18A and B, connected for push-pull parallel operation. The output of the voltage amplifier stage, V15A and V16A, is resistance coupled to the grids of driver tubes, V17A and V18A via C31 and R57. The output of the phase inverter stage, V15B and V16B, is resistance-coupled to the grids of driver tubes, V17B and V18B, through C32 and R60. The output of the driver stages is coupled to the primary of the interstage transformer, T5. The secondary of T5 is coupled to the push-pull parallel operated power amplifier stage, V19 through V24, through the parasitic suppressor resistors, R68 through R73.

Winding (8-9) on T6 supplies an inverse feedback voltage which is fed to the cathodes of the voltage amplifier stage, V15A and V16A, to reduce the effect of changing load conditions on the output voltage. The connections to the output of the power amplifier are from the 3-conductor jack, J2. The operation of each stage of the power amplifier in addition to the overall audio output can be checked by meter M2 and the 7-position meter switch, S3. Normal operation of each stage is indicated by a midscale reading on the meter with rated input signal and output load.

Oscillator

Each oscillator is capable of generating a variety of alarm signals although only four are used in this application: (1) collision, (2) chemical attack, (3) general, and (4) sonar. Each oscillator is also capable of generating four additional alarm signals which can be used in the event of future expansion of the system. The additional alarms are: (1) simulated motor-operated horn-type signal; (2) jump-tone signal which alternates between 600 and 1,000 cps at the rate of 1 1/2 cps; (3) jump-tone signal which alternates between 600 and 1,500 cps at the rate of 6 cps; and (4) simulated siren-type signal. However, these alarms are not discussed in this chapter.

Primary power for operation of the oscillator units (fig. 5-7) is supplied through terminals C and D of the multiconductor plug, P3, to the power transformer, T10. Filament power for all tubes is supplied by the filament winding of T10. High-voltage d-c plate power for the operation of the tubes is supplied by the parallel-connected rectifiers, V43 and V44, across the secondary 4-6 winding of T10 for full-wave rectification. The capacitor input filter comprising inductor L5 and capacitors C75, C74, and C73 is included in the plate power supply circuit to the various tubes.

Normal operation of an oscillator can be checked by measuring the plate current of the

various stages and the overall output by meter, M3, and meter switch, S4. The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading.

When any alarm is sounded, the sequence of relay operations is similar except that relays associated with the particular alarm are energized. The function of each individual relay in the system is explained in the applicable manufacture's technical manual furnished with the equipment. The operation of the oscillator for the various alarms is based on the system being set up for normal operation using oscillator 1 and channel A for circuit 1MC and channel B for circuit 6MC.

The COLLISION ALARM is a pulsed 1,000 cps signal. Each cycle of the signal consists of three pulses of 0.06 second and the third pulse is followed by an off period of 0.3 second. This cycle is repeated continuously as long as the collision alarm contact maker is actuated.

The closure of any collision alarm contact maker effectively shorts terminals AL1 and AL2 (fig. 5-1) to energize relay K37 (not shown) in the audio amplifier cabinet. Relay K37 for the collision alarm actuates relay K36 (not shown) which removes the control voltage from the other alarm relays to establish priority, and feeds the control power from pins L and H on the multiconductor plug, P3 (fig. 5-7), to relay K106. Relay K106 closes and grounds the cathodes of the phase-shift oscillator section V35B and V36B through R98 to produce a 1,000 cps signal. The output of V35B and V36B is fed through C57, R106, R105, R101, and C52, to the grids of V33 and V34 for amplification.

Relay K37 also energizes additional relays in the audio amplifier cabinet which in turn energize the collision alarm contactor associated with the oscillator in active service to pulse the 1,000 cps signal output of the oscillator and produce the collision alarm.

Tubes V33 and V34 function as a voltage amplifier to amplify the various signals generated by the oscillator assembly, except when they (V33 and V34) are under the effect of changing grid bias due to the operation of relay K105 (fig. 5-7) when the general alarm is being sounded. The output of V33 and V34 is coupled through C59 to the driver amplifier section, V35A and V36A. The output of V35A and V36A is coupled to the grids of V37A and V38A through C62 and potentiometer R119. A portion of the output of V37A and V38A is coupled to the grids of V37B and V38B through C63, R121, and R122. The input to the grids of V37B and V38B is 180 degrees out-of-phase with that at the grids of V37A and V38A. Thus V37 and V38 comprise a phase-inverter and balanced parallel push-pull power amplifier. The output of V37 and V38 is coupled through the impedance-matching transformer, T9, to the output terminals V and X of the multiconductor plug, P3.

The CHEMICAL ATTACK ALARM is a steady-tone signal of 1,000 cps. The closure of any chemical attack contact maker effectively shorts terminals AL3 and AL4 (fig. 5-1) to complete the control power circuit to relay K36 (not shown) provided that relay K37 (not shown) has not operated to establish a higher priority signal. The chemical attack signal is generated and amplified in the same manner as that described for the collision alarm signal. However, the contactor associated with the oscillator in active service is not energized and thus the signal is not pulsed.

The GENERAL ALARM is a simulated single-stroke gong-tone striking at the rate of 90 strokes per minute. The tone is caused to decay between strokes in a natural manner and the signal strokes are repeated automatically for 15 seconds after the alarm has been started. The signal-duration and stroke-repetition rate are determined by timing relays and contactors (not shown) in the audio amplifier cabinet but external to the oscillator assembly.

The momentary closure of any general alarm contact maker shorts terminals AL5 and AL6 (fig. 5-1) to complete the control power circuit to relay K35 (not shown) for the general alarm provided relays K37 for the collision alarm and K36 for the chemical attack alarm (not shown) have not operated to establish a higher priority signal. Relay K35 feeds the high side of the control power circuit through timing contacts of the general alarm contactor associated with the oscillator in active service. The timing contacts energize a holding relay (not shown) which is released after 15 seconds by the general alarm contactor. The general alarm contactor determines (1) the duration (15 seconds) of the general alarm, and (2) the 90 strokes per minute striking rate of the gong tone. An additional switch on the oscillator contactor pulses the visual alarm (busy lights on the microphone control stations) in step with the general alarm signal.

Pulsing the oscillator occurs when the circuit to pins K and T of the multiconductor plug, P3, (fig. 5-7), is interrupted at the rate of 90 times per minute. Energy from pins S and H of P3 closes relays K105 and K107. Relay K107 closes relays K103 and K106. The circuit for relay K106 is from pin P (which is the same polarity as pin S) or P3, through contacts 6-7 of relay K107, through the coil of relay K106, and to pin H of P3. The circuit for relay K103 is from pin P of P3, through contacts 2-3 of relay K107, through the coil of relay K103, and to pin H of P3.

Relay K106 connects the cathodes of V35B and V36B through the bias resistor, R98, to ground to supply normal bias for the 1,000-cycle phase-shift oscillator stage. The output of V35B and V36B is coupled through C57, R106, R105, and C52 to V33 and V34 which function as a voltage amplifier.

Relay K103 applies plate voltage through the plate-load resistor, R99, to the plates of the 1,500-cycle phase-shift oscillator V31A and V32A. Cathode bias is supplied to the 1,500-cycle phase-shift oscillator through controls on relay K102 to resistor R83 and ground. This connection furnishes cathode coupling to the 1 1/2 cps phase-shift oscillator, V29A and V30A, for the production of other alarm signals. Hence, relay K102 must remain in its nonoperated condition during the production of the general alarm signal. The output of the 1,500-cycle oscillator, V31A and V32A, is coupled through R90 and C52 to the voltage amplifier, V33 and V34.

The signal through V33 and V34 is cut off when relay K105 actuates to remove ground from grid resistor R102 and apply cut-off bias from R145 in the power supply. The reduction of the signal transmission through V33 and V34 occurs gradually as a function of the time constant of R103 and C53 as C53 charges. Thus, the associated general alarm oscillator contactor, K53, (not shown) operates 90 times per minute to interrupt the circuit between power pulses from terminals T and K of plug P3 to alternately permit signal transmission through the voltage amplifier, V33 and V34, and thus to cause its decay in a manner that closely resembles the striking of a gong. Amplification is obtained from the driver stage, V35A and V36A, and the power amplifier, V37 and V38, as previously described for the collision alarm.

The SONAR ALARM is a jump-tone signal alternating between 600 and 1,500 cps at the rate of 1 1/2 cycles per second. The closure of any sonar alarm contact maker shorts terminals AL7 and AL8 (fig. 5-1) to complete the control power circuit to relay K34 for the sonar alarm provided that relays K35, K36, and K37 (not shown) have not operated to establish a higher priority signal. Relay K34 connects the high side of the control power circuit from pin N on the plug P3 to relay K108 (fig. 5-7) returning to pin H of P3. Relay K108 closes and energizes relay K104 which applies plate voltage to the 600 cps phase-shift oscillator, V31B and V32B. Relay K104 also energizes relay K103 which applies plate voltage to the 1,500 cps phase-shift oscillator, V31A and V32A.

The closure of relay K108 also applies plate voltage to the 1 1/2 cps oscillator, V29 and V30. The plates of V29A and V30A are coupled to the grids of V29B and V30B through C42. The plates of V29B and V30B are coupled to the grids of V29A and V30A through C43, thus, V29 and V30 are parallel triodes connected as a free running multivibrator having a frequency of 1.5 cps. The cathodes of V29A and V30A are connected to the cathodes of the 1,500 cps phase-shift oscillator, V31A and V32A. Likewise, the cathodes of V29B and V30B are connected to the cathodes of the 600 cps phase-shift oscillator, V31B and V32B. Hence, the multivibrator oscillator, V29 and V30, causes V31A-V32A and V31B-V32B to conduct on alternate half cycles and to generate a jump-tone signal alternating between 600 cps and 1,500 cps at 1 1/2 cycles per second.

The output of V31A and V32A is through C46 and R90 to the grids of V33 and V34 via C52, and the output of V31B and V32B is through C45 and R89 to the same grids. Further amplication is obtained from the driver stage, V35A and V36A, and the power amplifier, V37 and V38, as previously described for the collision alarm.

The 1/3 cps fixed-frequency multivibrator, V39 and V40, and the 750 to 1,750 cps oscillator, V41 and V42, are provided to generate additional alarm signals in the event of future expansion of the announcing system.

OPERATION

The path of circuits 1MC and 6MC from the inputs to the loudspeakers is shown by the block diagram in figure 5-4. The selector switch for the oscillators and amplifiers is set for normal operation with oscillator 1 and both amplifiers in

active use. Channel A is normally used for circuit 1MC and channel B for circuit 6MC. In case of failure of a preamplifier or power amplifier, both circuit 1MC and circuit 6MC can be switched for operation on either channel A or channel B. When both circuits, 1MC and 6MC, are switched to the same channel (fig. 5-4), circuit 1MC has priority over circuit 6MC operation.

Circuit 1MC Microphone Control Station

To make voice announcements from a circuit 1MC microphone control station, operate one or more of the loudspeaker group selector switches (fig. 5-2) to select the area or areas to receive the announcement. Observe the busy indicators.

When BUSY 1 lamp is lighted, circuit 1MC amplifier is in use. Except in an emergency, do not attempt to use circuit 1MC when BUSY 1 lamp is lighted. If another microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk switch, the transmission from both microphone control stations will go out to all loudspeaker groups selected by both microphone stations.

When BUSY 2 lamp is lighted, circuit 6MC amplifier is in use and will have no effect on circuit 1MC operation.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted irrespective of the amplifier in use; (2) both circuit 1MC and circuit 6MC are in use, and if another microphone control station attempts to use circuit 1MC the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations; or (3) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and one or the other circuit is in use.

Circuit 1MC takes priority over circuit 6MC, therefore, if circuit 6MC is in use and a circuit 1MC loudspeaker group is selected from another microphone control station, circuit 6MC will be cut off when the microphone press-to-talk switch is operated and the announcement will go out to the circuit 1MC loudspeakers only. If circuit 1MC is in use and a circuit 1MC loudspeaker group is selected, the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations.

Circuit 1MC-6MC Microphone Control Station

To make voice announcements from the 1MC-6MC microphone control station, operate the intership selector switch (fig. 5-2) to the circuit 6MC bull horns. Observe the busy indicators as previously described.

When the BUSY 1 lamp is lighted, circuit 1MC is in use, but circuit 6MC can be selected and used at the same time without interference to the transmission on circuit 1MC. Except in an emergency, do not attempt to use circuit 1MC when the BUSY 1 lamp is lighted. If a microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk (microphone) switch when the BUSY 1 lamp is lighted, the transmission from both microphone stations will go out to all circuit 1MC loudspeaker groups selected by both microphone stations.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted; or (2) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and circuit 1MC is in use from another microphone control station. Because circuit 1MC has priority over circuit 6MC, it is not possible to use circuit 6MC when both the BUSY 1 and BUSY 2 lamps are lighted. If a circuit 1MC loudspeaker group is selected and the press-to-talk switch is operated, the transmission from both microphone control stations will go out to all circuit 1MC loudspeakers selected by both microphone stations.

Alarm Contact Maker

The operation of an alarm contact maker will take precedence over any microphone control station. When an alarm is sounded, the BUSY 1 and BUSY 2 indicators are lighted at all microphone control stations and the alarm signal is transmitted to all circuit 1MC loudspeakers. With the exception of the general alarm, the alarm signals will be sounded only as long as the contact maker is held in the operated position. The general alarm signal, once started by momentary operation of the general alarm contact maker, will continue for 15 seconds. This alarm can be repeated by again momentarily closing the general alarm contact maker.

Audio Amplifier Cabinet

Normal operation does not involve the operation or switching of controls at the audio amplifier cabinet, provided the switches and controls are set for normal operation or switching of controls (fig. 5-3). The meters on each oscillator and amplifier assembly can be observed for normal operation by placing the meter switch in position 1.

During the transmission from a microphone control station, normal operation of the preamplifier and power amplifier in active use is shown by a meter reading which swings to 0 db on voice peaks. During the transmission of alarm signals, normal operation of an oscillator in active service depends on the nature of the alarm signal. Normal operation of an oscillator on general alarm is indicated by a reading which swings from no reading to midscale (0 db). During alarm signals the preamplifier is bypassed. Normal operation of a power amplifier in active service is indicated by a reading within ±2 db of the meter reading for the oscillator.

MAINTENANCE

If the entire announcing system is inoperative, the trouble is probably in the ship's power supply or wiring from the ship's power supply. Check the power available indicator on the audio amplifier cabinet (fig. 5-3). This indicator, unless it is defective, will be lighted when power is available at the cabinet.

Check the fuses in the early stages of trouble shooting. The primary power and control circuits are fused on both the high and low sides. All fuses are located on the control panel of the audio amplifier cabinet in combination fuse holders and blown-fuse indicators, and are accessible from the front of the cabinet. Failure of a fuse is indicated when the neon-glow lamp in the fuse-holder cap is lighted. The switch controlling power to the circuit (which a fuse protects), must be in the ON position for the glow lamp to give an indication of fuse failure. Also, in the case of fuses protecting microphone control stations, the microphone talk switch at the microphone control station must be operated to give an indication of fuse failure.

Performance failure of the shipboard announcing equipment can be corrected most readily by first isolating the assembly at fault, then isolating the circuit of that assembly, and finally by isolating the particular part causing the trouble. Localization of trouble in the system will be comparatively simple because of the test facilities included in the equipment. Also, the use of duplicate oscillator, preamplifier, and power amplifier assemblies permits the testing or repair of one assembly while the other assembly remains in active service, thereby avoiding the necessity for shutting down the system. Trouble in an assembly can be localized readily by using the meter and meter switch included in each assembly (fig. 5-3). In most cases a faulty assembly or even the faulty stage of an assembly can be localized by these meters without resorting to extensive troubleshooting procedures.

Microphone Control Station

A short circuit in the wiring to a microphone control station or a defect in a microphone control station can, under certain circumstances, prevent normal operation from other microphone control stations. In the event of such trouble, operate the microphone station disconnect switch to the OFF position. If the location of the defective microphone station is not known, operate all microphone station disconnect switches on the audio amplifier cabinet (fig. 5-3) to the OFF position, one at a time until the defective microphone control station is isolated. Leave this switch in the OFF position until the trouble has been corrected. Return all other microphone-station disconnect switches to the ON position.

Loudspeaker

A short circuit in a loudspeaker or in the loudspeaker wiring can cause a power amplifier, which tests normally, to act abnormally when switched into active service. It will result in a lower than normal meter reading of the power amplifier output. If the location of the defective wiring or loudspeaker is not known, operate the loudspeaker-group disconnect switches on the audio amplifier cabinet (fig. 5-3) to the OFF position, one at a time until the defective loudspeaker group is isolated. This will be indicated by a return to normal meter reading (0 db ± 2 db) of the power amplifier.

If the trouble persists and is not in the microphone control stations or loudspeaker groups, it is probably in the preamplifier, power amplifier, or oscillator assembly.

Preamplifier

Normal output of a preamplifier is 10 volts which is indicated by a midscale reading of 0 db ±2 db on the output meter with the meter transfer switch in position 1. Normal output is obtained from a preamplifier when the voice signals from a microphone control station are applied to the input terminals, or when attenuated alarm signals from an oscillator being tested (or being used as a source of test signal) are applied to the same terminals. In normal system operation, the alarm signals generated by an oscillator in active service bypass the preamplfier in active service and are applied directly to the input of the power amplifier in active service.

To check a preamplifier for normal operation, apply an attenuated signal from the oscillator not in active service to the input transformer, T1, of the preamplifier and observe the output meter readings from each meter switch position (fig. 5-5). Operate the test chemical attack alarm switch to the ON position (fig. 5-3) to cause the oscillator not in active service to generate a 1,000 cps signal. This signal is attenuated and fed to the preamplifier on test through the test input control. The normal test signal input to the preamplifier will indicate a midscale reading of 0 db ±2 db for the normal outputs of the various stages.

When the meter switch, S2, (fig. 5-3) is rotated to positions 1 through 7 inclusive, the output meter, M1, is connected to terminals in the various output stages of the preamplifier (fig. 5-5) as follows: position 1, terminals M-MM of the audio output transformer, T2; position 2, terminals A-AA of the power amplifier stage (V5 and V6); position 3, terminals B-BB of the driver stage (V3 and V4); position 4, terminals C-CC of the voltage amplifier stage (V1 and V2); position 5, terminals D-DD of the compressor stage (V7 and V8); position 6, terminals E-EE of the phase inverter stage (V11A and V12A); and position 7, terminals F-FF of the limiter stage (V11B and V12B). If other than a normal reading is obtained, check the voltage of the stage or stages at fault and compare the readings with those listed in the applicable manufacturer's technical manual. Localize the trouble and replace the defective part.

Power Amplifier

Normal audio output of a power amplifier is 70 volts which is indicated by a reading of 0 db on the output meter with the meter switch in position 1 (fig. 5-3). In normal operation, alarm signals from the oscillator in active service drive the power amplifier to normal output. Likewise, the amplified voice signals from the preamplifier will drive a power amplifier to normal output.

During test, the oscillator not in active service is used to drive the preamplifier (not in active service) through a loss pad consisting of R127, R128, and R129, in the secondary of the output transformer, T9, of the oscillator (fig. 5-7). The preamplifier, in turn, drives the power amplifier not in active service. The audio output of the power amplifier is fed to a dummy-load resistor combination consisting of R74, R75, and R76 in the secondary of the output transformer, T6, of the power amplifier (fig. 5-6). Switching arrangements in the audio amplifier cabinet prevent the test signals from reaching the loudspeakers.

In the majority of cases, trouble in any stage of the power amplifier will also affect the meter reading when measuring the output signal. Therefore, when an abnormal signal output is indicated on the meter, localize the trouble by using the power amplifier meter and meter switch to check the operation of all the stages.

To check a power amplifier for normal operation, operate the TEST START switch to the ON position (fig. 5-3) and observe the output meter readings from each meter switch position. The normal test signal input to the power amplifier should indicate a midscale reading of 0 db for normal audio output, and a midscale meter reading of 0 db ± 2 db will indicate normal output for the other stages of the power amplifier.

When the meter switch, S3, is rotated to positions 1 through 7, inclusive, the output meter, M2, is connected to terminals in the various stages of the power amplifier (fig. 5-6) as follows: position 1, terminals M-MM of the output transformer T6; position 2, terminals A-AA cathode bias volts of the power amplifier stage (V19 through V24); position 3, terminals B-BB cathode voltage of the driver stage (V17A) across R63; position 4, terminals C-CC cathode voltage of the driver stage (V17B) across R64; position 5, terminals D-DD cathode volts of the driver stage (V18A) across R66; position 6, terminals E-EE cathode volts of the driver stage (V18B) across R67; and position 7, terminals F-FF plate current of the phase-inverter stage (V15B and V16B) across R57. If an abnormal meter reading is

indicated, check the voltage of the stage or stages at fault with the normal readings listed in the manufacturer's technical manual. Isolate the trouble and repair or replace the defective component.

Oscillator

Normal output of an oscillator is 10 volts which is indicated by a midscale reading of 0 db with the meter switch in position 1 (fig. 5-3). On general alarm, collision alarm, and sonar alarm, this reading swings from no reading to 0 db. The 1,000 cps test chemical attack alarm signal is used for adjusting the amplifier. It is essential that an output of 0 db be obtained from the oscillator.

Normal operation of each stage of an oscillator is indicated by the correct meter reading, when the meter, M3, is switched into each stage by meter switch, S4, and the various test alarm switches are operated. It is important to note that no reading will be obtained from some positions of the meter switch when alarms (test or actual) are being sounded. When trouble shooting an oscillator, be certain that a normal meter reading is not obtained for the particular stage before attempting to localize trouble within the stage. In most cases, trouble in one stage will also affect the meter reading when measuring the oscillator output with the meter switch in position 1.

When an abnormal output is indicated, localize the faulty stage by checking the operation of each stage. Rotate the meter switch, S4, through its various positions and compare the readings of meter, M3 (fig. 5-7), with the normal readings listed in the manufacturer's technical manual. To avoid needless checking of the stages not used on any particular signal, check only the following stages when testing the individual signals.

(1) Test chemical attack—S4 positions 1, 2, 3, 4, and 7.
(2) Test collision alarm—S4 positions 1, 2, 3, 8, and 9.
(3) Test general alarm—S4 positions 1, 2, 3, 4, 6, 7, and 9.
(4) Test sonar alarm—S4 positions 1, 2, 3, 5, 6, and 10.

If any of these readings are above or below normal (0 db) by more than 2 db or if no reading is obtained, make a voltage test of the faulty stage or stages and compare the readings with the normal readings listed in the technical manual. Localize the trouble and repair or replace the faulty component as necessary.

The scope of this training course does not permit a complete coverage of all the troubles, tests and adjustments of shipboard announcing equipment. More detailed information is contained in the manufacturer's technical manual furnished with the equipment installed aboard your ship.

INTERCOMMUNICATING SYSTEM

An intercommunicating system consists of a number of identical, permanently located stations. Each station contains all the necessary components to provide two-way amplified voice communication, supplemented by signal lamps, between any two stations or from one station up to four other stations simultaneously.

An intercommunicating system is more flexible and more reliable than a central amplifier announcing system. The flexibility is evidenced by the fact that up to five independent conversations can be carried on simultaneously. The reliability is evidenced by the fact that if one amplifier becomes inoperative, all the other stations in the system can continue to transmit and receive. The station having the defective amplifier can receive but it cannot transmit.

INTERCOMMUNICATING UNIT

Intercommunicating units installed in naval vessels are of standard design (fig. 5-8). The term "standard" indicates that all units are identical with respect to their electrical characteristics. This standardization permits the units, irrespective of their mechanical construction, to be connected together electrically in a system. The electrical characteristics that must be identical to permit interconnection in a system are the (1) audio amplifier input and output power requirements; (2) amplifier output impedance to the loudspeaker line transformer; (3) supply voltages and currents; (4) call and busy signal voltages; and (5) interconnection circuits.

Standard intercommunicating equipment consists of the wired audio reproducing type of unit. The intercom units consist of two types. One type can originate calls up to a maximum of 10 other stations, and the other type can originate calls up to a maximum of 20 other stations. There

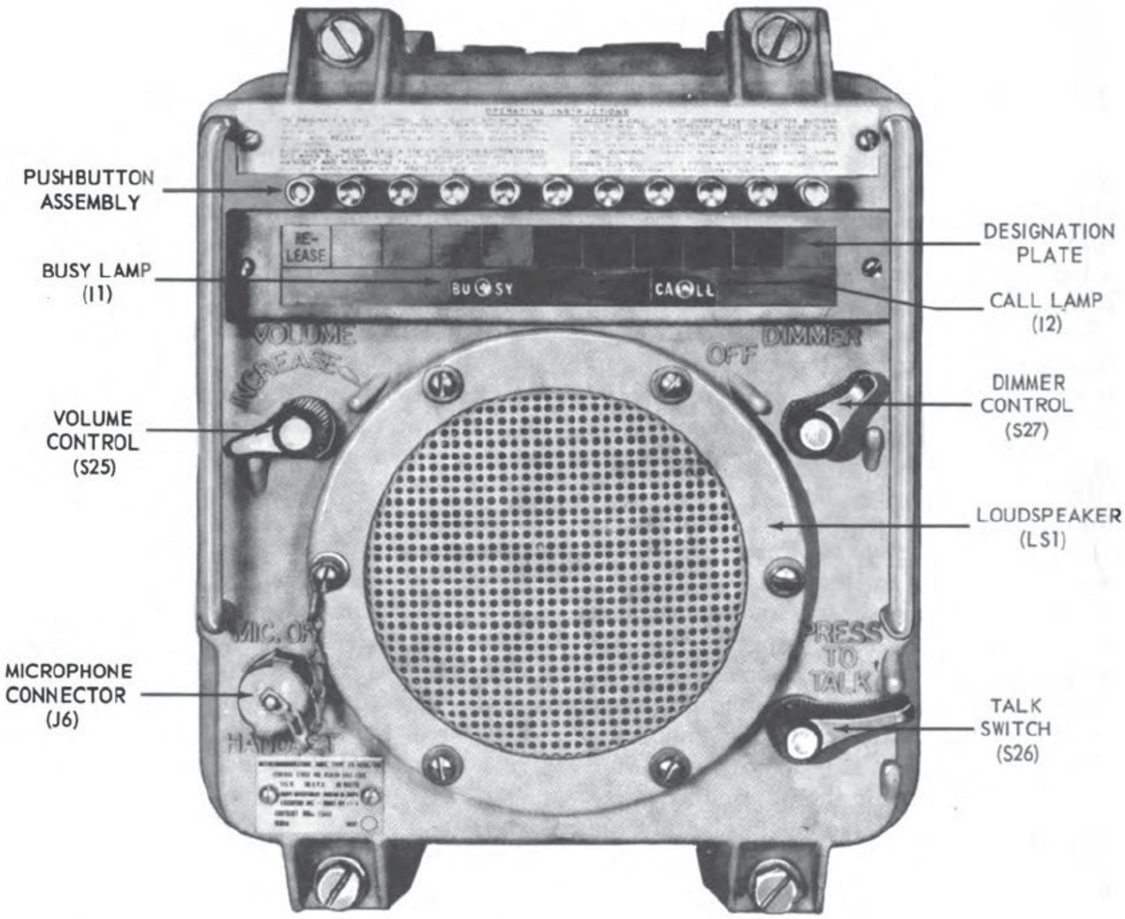


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Figure 5-8.—Intercommunicating unit.

is no operational difference between the two types of units. The schematic diagram of a standard intercommunicating unit is illustrated in figure 5-9.

The ship's power for the intercommunicating system is controlled by a master switch on the I.C. switchboard and is supplied through a TSGA cable. The TSGA cable interconnects the units in parallel for the single-phase 115-volt power supply and the signal circuit common line. The 115-volt power is fused at each unit. The audio and signal lines (excluding the signal circuit common) of the units in the system are interconnected with a TTHFWA cable.

The intercommunicating unit (fig. 5-8) is housed in a steel cabinet designed for bulkhead mounting. It will withstand shock, vibration, and salt spray, and will perform under extremes of temperature and high humidity. The components consist essentially of a reproducer, controls, and amplifier.

Reproducer

The reproducer serves as a microphone to transmit sound from the unit to other units in the system and as a loudspeaker to reproduce sound transmitted to the unit by any other unit. An incoming call can be heard through the loudspeaker because amplification is accomplished by the amplifier of the calling unit.

Controls

The controls consist of the talk switch, handset and microphone talk, pushbutton assembly, busy light, call light, volume control, and dimmer control.

The TALK SWITCH, S26, serves to select the function of the reproducer. When the switch is depressed, the reproducer functions as a microphone and the output of the amplifier of the calling station is electrically connected to the reproducer of the called station. When the switch is released the reproducer functions as a loudspeaker. The talk switch is spring loaded and returns to the listen or standby position when released.

A HANDSET can be used with the intercommunicating unit in place of the reproducer. The operation is the same as that of the reproducer except that the pushbutton in the handset is used as a talk switch in place of the regular talk switch on the front panel. Incoming calls will be heard simultaneously in the handset and in the reproducer. The volume control will control the level of the incoming call to the reproducer only.

A PORTABLE MICROPHONE can also be used with the equipment. The operation is the same as that of the reproducer, except that the pushbutton on the microphone is used as a talk switch instead of the regular talk switch on the equipment.

The PUSHBUTTON ASSEMBLY, or station selector buttons, are located at the top of the front panel (fig. 5-8). The locations or designations of the various units in the system are engraved in the station designation plate below the associated selector buttons. When the station selector buttons are depressed they will lock in the operated position until the release pushbutton is depressed to return them to the nonoperated position.

The 10-station unit is provided with one bank of station selector switches (fig. 5-8), whereas the 20-station unit is provided with two banks of selector switches. In the 20-station unit, however, the latchbar switches and release pushbuttons are electrically interconnected.

One bank of selector switches consists of the switch mechanism, 11 pairs of spring pile-up switches, and a latch-bar switch. Each pair of pile-up switches (consisting of an upper pile-up designated S1U, S2U, and sc forth, and a lower pile-up designated S1L, and so forth, is operated simultaneously by a separate release pushbutton.

During standby periods the release pushbutton is kept in the depressed, or operated position. When any station selector button is depressed, the release pushbutton will automatically return to the nonoperated position and the release lamp under the pushbutton will be lighted. At the conclusion of a conversation the release pushbutton must be depressed to extinguish the release lamp and return any station selector buttons which were operated, to the nonoperated position.

The BUSY lamp is lighted when a station button is depressed to call another station and the station being called is busy. Do not leave a station selector button depressed when the busy lamp is lighted. Depress the release pushbutton and call later.

The DIMMER CONTROL, S27, (fig. 5-8) controls all illumination of the unit. The signal lights are off when the control knob is in the extreme counterclockwise position and are fully lighted for all other positions as the knob is turned clockwise. The station designation lights are lighted for all positions of the control knob and the illumination increases as the knob is turned clockwise.

The VOLUME CONTROL, S25, increases the loudness of the incoming signal as the knob is turned clockwise. The volume control switch is associated with a variable impedance output transformer, T2, inside the unit. As the knob is rotated, the electrical energy passing through the transformer to the loudspeaker is increased and the volume of sound output of the loudspeaker is correspondingly increased. This control has no effect on the volume of the outgoing sound from the unit. Thus, each unit in the system can control the incoming volume to the desired level.

Amplifier

The amplifier is a 3-stage push-pull amplifier consisting of the input transformer, T1, double triodes, V1 and V2, beampower tubes, V3 and V4, output transformer, T2, and the power supply rectifier twin diode, V5 (fig. 5-9).

The primary of T1 is tapped to match it either to the internal loudspeaker, LS1, used as a microphone, or to an external microphone over a frequency compensating network consisting of R21, R22, R23, and C12. The secondary of T1 drives the grids of the first voltage amplifier stage, V1.

Resistance-capacitance coupling is used between the three stages of the amplifier. The output of the power stage, V3 and V4, is coupled through the output transformer, T2, to the voice

transmission line. When the amplifier is not in use (when receiving calls), transformer, T2, acts as a line transformer. Calls are received over the voice transmission line and are coupled over a separate winding to the loudspeaker, LS1. This winding is provided with taps connected to the switch-type volume control, S25, to change the step-down voltage ratio of T2 and thus control the volume of the incoming signal.

During the standby periods the plate current of V2 is cut off completely and the plate current of the output tubes, V3 and V4, is reduced to a very low value. This reduction in plate current is accomplished by the voltage drop across R12 connected between the center tap of the high-voltage winding of T3 and ground. This voltage increases the bias on V3 and V4. The d-c voltage on the filter capacitors C7, C8, and C9 is substantially the same during standby periods (no load) and during periods of speech (load) because R12 changes the rectifier circuit from capacitor-input (with load) to resistor-input on no load. The reduced voltage with capacitor input on load is approximately the same as with resistor input on no load. Resistor, R12, is in series with C9 during standby periods.

This type of cut-off circuit eliminates voltage surges on the capacitors when switching from standby to ready conditions and also eliminates the delay caused by charging of the capacitors. To ready the amplifier for outgoing speech, R12 is shorted by operating the loudspeaker, LS1, talk switch, S26 (terminals 7 and 8); by pressing the pushbutton in the auxiliary handset or microphone (terminals C and D on J6); or by operating an external switch connected to terminals S5 and GND (fig. 5-9).

The upper end of resistor, R11, is connected from the junction of R8 and R9 to ground (R12 being shorted during ready periods). Any unbalance in the audio voltages reaching the grids of V3 and V4 will develop a voltage across R11. The upper end of resistor, R11, is also connected to terminal 5 of the feedback winding on T2. Terminal 6 of this winding is connected to the V2A grid via R4 and terminal 4 is connected to the V2B grid via R5. The unbalanced voltage developed across R11 will be fed back to the grids of V2A and V2B through R4 and R5 respectively in the proper phase to correct the unbalanced condition. The cathode circuit of V2A and V2B is returned to ground through contacts 3-4 of the talk relay, K1.

Negative feedback is incorporated in the design of the amplifier to lower the apparent output impedance and to develop a 70-volt output (within 3 db) when the amplifier is delivering 10 watts to any combination of from one to four other intercommunicating units. The feedback is developed by the separate winding on the combination output-line transformer, T2 (terminals 4, 5, and 6). The voltage is fed back symmetrically to the grids of V2 through R4 and R5.

OPERATION

To call a particular station, depress the station selector switch of the desired station (S2 through S11), depress the talk switch, S26, and speak directly into the grille (fig. 5-8). Release the talk switch, S26, to listen. When the conversation is completed, depress the release pushbutton, S1, to return the selector pushbutton to the nonoperated position.

To accept a call from another station, listen to the incoming call through the loudspeaker. Do not operate any of the station selector pushbutton switches. Depress the talk switch, S26, to reply to the incoming call. The call light is illuminated to indicate the station is being called by another station. If the call light remains illuminated after the conversation is completed, remind the calling station to depress his release pushbutton.

The audio circuit between two stations is illustrated by the simplified schematic diagram in figure 5-10. The talk switches at both stations are shown in the normal (listen) position. When the talk switch, S26, at either station is depressed, the voice coil leads of the loudspeaker are shifted from terminals 7 and 13 of the secondary of T2 to the input transformer, T1, of the associated amplifier. At the same time contacts 7-8 of S26 (fig. 5-9) are closed to short resistor, R12, to ground, thereby decreasing the bias on V3 and V4. This action increases the V3 and V4 plate current through the operating coil terminals 7-8 of relay, K1. The increase in plate current operates relay, K1, to close contacts 3-4 and complete the circuit from the V2 cathodes through R6 to ground. This action applies plate voltage to V2 and the amplifier at the talking station is placed in the ready condition.

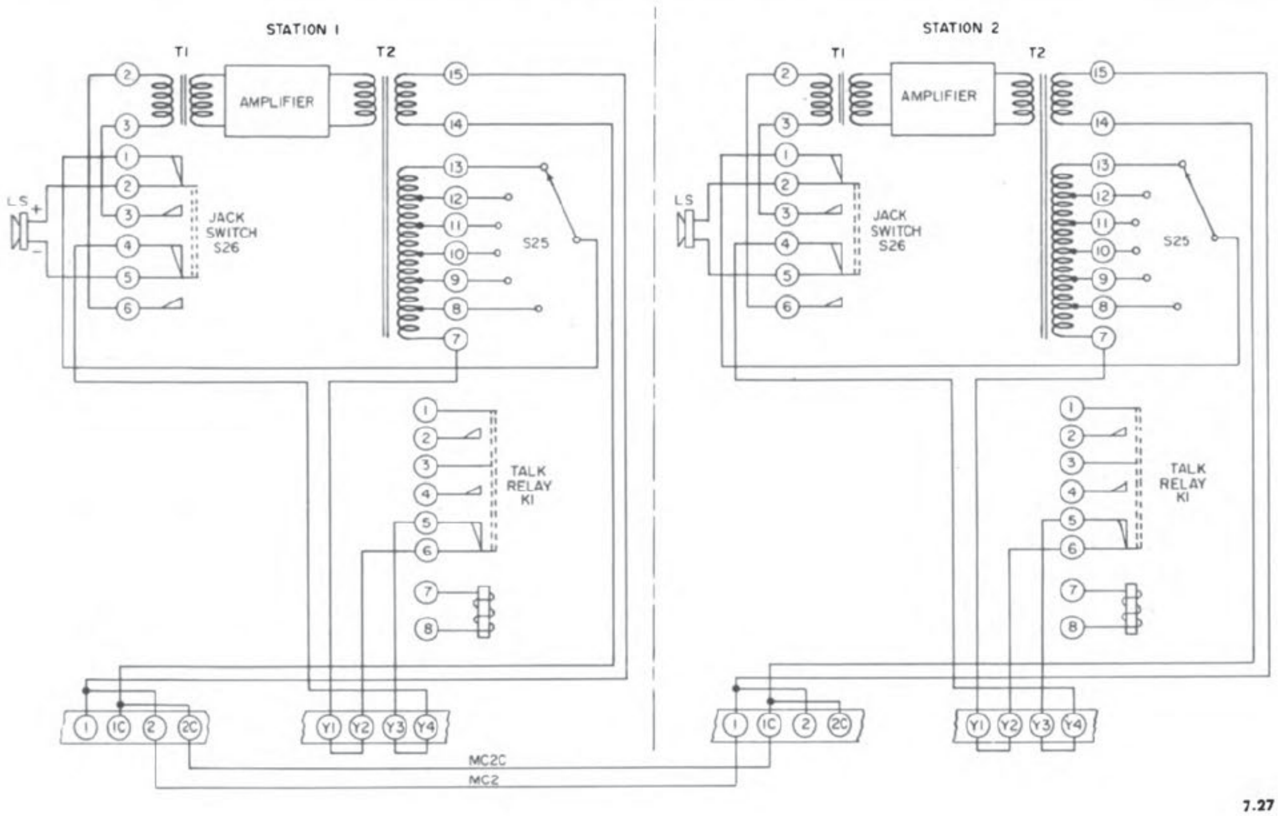

Figure 5-10.—Schematic diagram of audio lines between two stations.

The voice signals are amplified and applied to terminals 14 and 15 of T2 at the listening station and appear across terminal 7 of T2 and the moving contact of the volume control, S25, and then to the loudspeaker.

The amplifier of the listening station is in a standby condition. In the standby condition the plate current of V2 (fig. 5-9) is completely cut off, and that of V3 and V4 is reduced to a very low value by the voltage drop across R12, which is in the negative high-voltage center tap 2 of T3 to ground.

Station 1 Calling Idle Station 2

The signaling circuits between two stations are illustrated by the simplified schematic diagram in figure 5-11. Terminal 9 of the 16-volt winding of the power transformer, T3, in both stations is connected through terminal XX to the signal circuit common MCXX, which is connected in parallel with all XX terminals throughout the system. Terminal 8 of T3 at station 1 is connected to terminal 8 of the busy relay, K2. When the station selector pushbutton switch, S2, is depressed to call (idle) station 2, the release pushbutton, S1, will be released as soon as S2 is depressed. The latchbar switch, S23, will operate to momentarily connect terminal 7 of the busy relay, K2, to the signal line, MC2X. The circuit is from terminal 7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, and to line MC2X. If station 2 is idle, line MC2X will be connected to terminal 8 of T3 at station 2. The circuit is from line MC2X to terminal 1X of station 2, contacts 6-7 of S1, through call lamp I2, and to terminal 8 of T3.

During the time that latchbar switch, S23, is momentarily operated, terminal 7 of busy relay, K2, at station 1 is connected to terminal 8 of T3 at station 2 through call lamp I2. Terminal 8 of K2 at station 1 is connected to terminal 8 of T3 at the same station. Terminal 8 of T3 at station 1 is at the same potential as terminal 8 of T3 at station 2 and K2 does not operate.

As soon as latchbar, S23, releases, terminal 7 of busy relay, K2, is open circuited and the connections of both the audio (heavy) lines and the signal (light) lines between the two stations are established. The call lamp, I2, is lighted at station 2. The signal circuit is from terminal 8 of T3 to I2, contacts 7-6 of S1, to terminal IX, over signal line MC2X to terminal 2X of station 1, contacts 1-2 of S2, contacts 2-1 of S23, to terminal XX, over signal common line MCXX, to terminal XX of station 2, and to terminal 9 of T3.

The release lamp, I3, at station 1 is lighted (S1 released when S2 was depressed). The circuit is from terminal 7 of T3 at station 1, to release lamp I3, contacts 1-2 of S1, and to terminal 6 of T3. Line MCIX is connected to line MCXX. The circuit is over line MC1X to terminal 1X of station 1, contacts 6-5 of S1, to terminal XX of station 1, and to signal line common MCXX. Line MC2X is also connected to line MCXX. The circuit is from terminal 2X of station 1, contacts 1-2 of S3, contacts 2-1 of S23, to terminal XX of station 1, and to line MCXX.

Station 1 Calling Busy Station 2

When the station selector pushbutton switch, S2, is depressed at station 1 to call station 2, which is busy (line MC2X connected to line MCXX by another parallel connected station not shown), the release pushbutton, S1, will be released as soon as S2 is depressed. The latchbar switch, S23, will momentarily operate to energize the busy relay, K2. The circuit is from terminal 8 of T3, terminals Y7-Y6 of station 1, terminals 8-7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, over signal line MC2X to terminal 1X of station 2, contacts 6-5 of S1 (released), terminal XX of

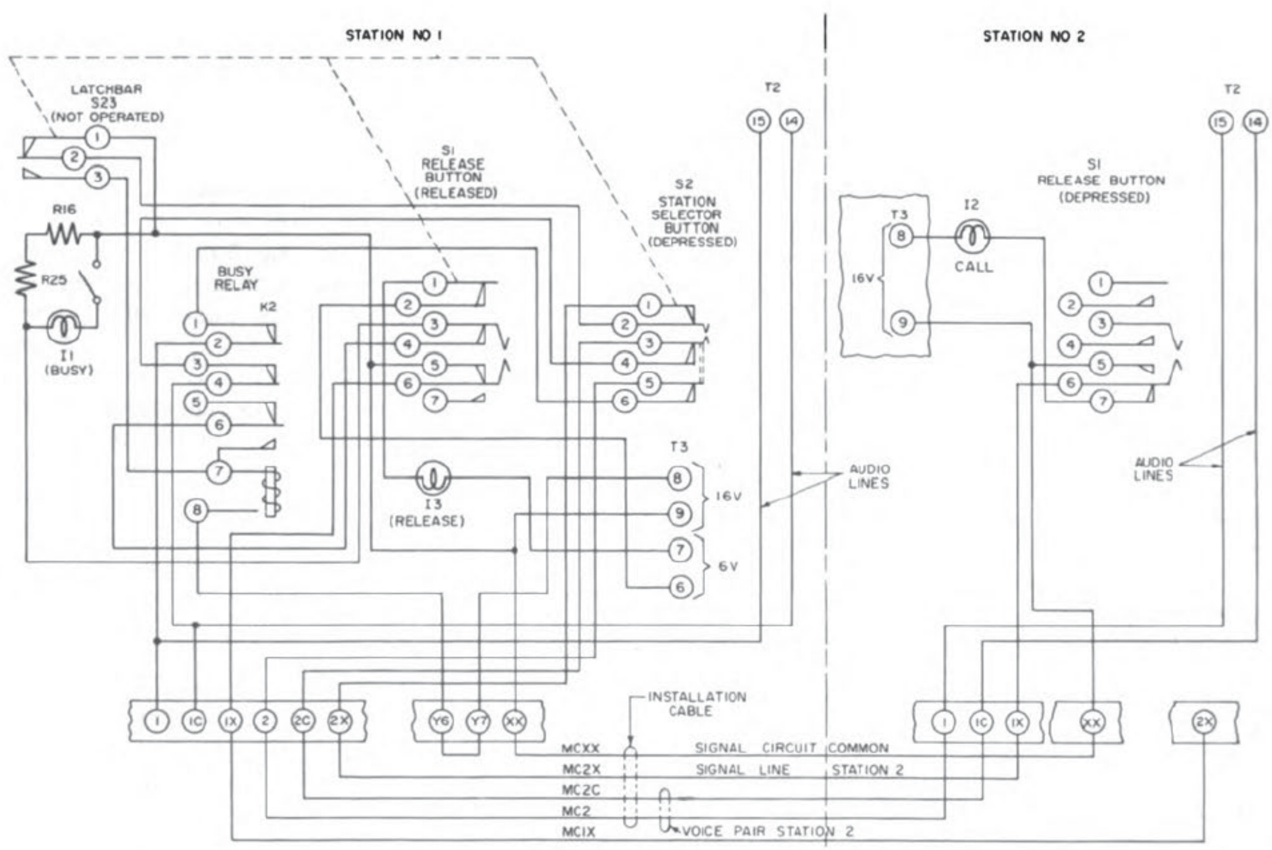

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Figure 5-11.—Schematic diagram of signaling circuits between two stations.

station 2, over signal common MCXX, terminal XX of station 1, and to terminal 9 of T3.

The busy relay, K2, will lock in the operated position after latchbar switch, S23, opens. The circuit is from terminal 8 of T3, terminals Y7-Y6, terminal 8 and contacts 7-6 of busy relay K2, contacts 4-3 of S1, to the busy lamp I1, and to terminal 9 of T3. The busy lamp, I1, is now in series with the coil of busy relay, K2, and will be lighted. The audio lines from terminals 14 and 15 of T2 to line MC2 and line MC2C will be open at contacts 3-4 and 1-2, respectively, of busy relay, K2, which is operated.

The normal connection of the audio line from terminal 14 of T2 (station 1) is through contacts 4-3 of busy relay, K2 (released), contacts 4-3 of S2 (depressed), to terminal 2C, and to line MC2C. The normal connection of the audio line from terminal 15 of T2 is through contacts 2-1 of busy relay, K2 (released), contacts 6-5 of S2 (depressed), to terminal 2, and to line MC2.

Parallel Operation of Two Adjacent Stations

The operation of two intercom stations in parallel is illustrated by the simplified schematic diagram in figure 5-12. The incoming speech from a remote station will be heard at both stations 3 and 3A, and replies can be made from either station. Either station can call a third station but both stations cannot call at the same time. When the talk switch, S26, at station 3 is depressed to transmit a message, the talk relay, K1, at station 3A is operated to open the circuit to the loudspeaker and prevent acoustic feedback (not shown).

The incoming speech lines, 1 and 1C, of station 3 are connected to terminal 15 and 14 respectively on transformer, T2.

The 14-15 winding of T2 at both stations couples the incoming speech to the tapped windings of T2 which include the volume controls, S25. Thus the incoming signals appear across terminals 7 of T2 and the moving contact of the

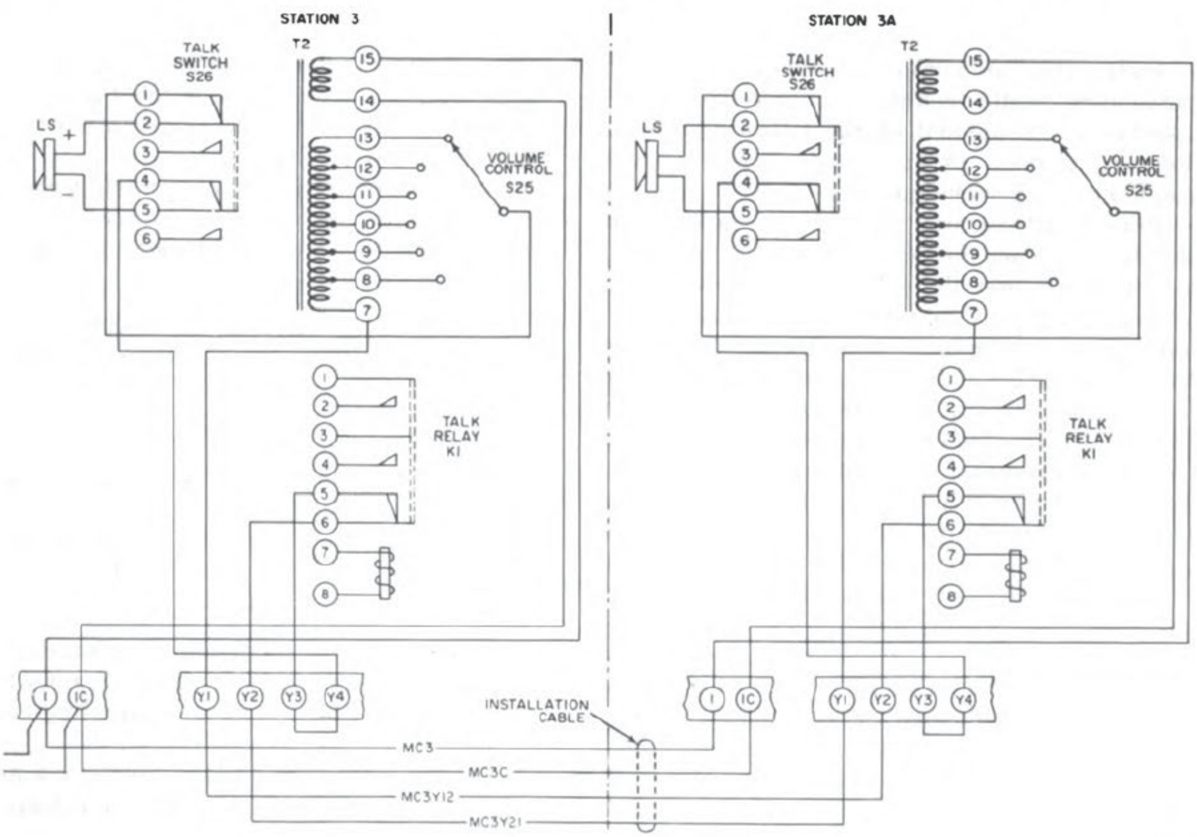

Figure 5-12.—Schematic diagram of two stations in parallel.

volume control, S25, at both stations. These signal sources are connected in series addition through a closed loop containing both loudspeakers.

The circuit is from the arm of S25 at station 3, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, terminals Y4 and Y3, contacts 5-6 of K1, terminal Y2 over line MC3Y21 to terminal Y1 of station 3A, terminal 7 of T2, the arm of S25, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, to terminals Y4-Y3, contacts 5-6 of K1, terminal Y2, over line MC3Y12, terminal Y1 in station 3, to complete the circuit at terminal 7 of T2.

The volume at both stations will be the same and can be controlled by either volume control, S25. Both volume controls, however, should be kept at the same setting.

If the talk relay, K1, is operated at either station, the input to the audio circuit will be open for both stations.

TROUBLESHOOTING

Instruction manuals are invaluable aids. Because no single trouble is emphasized, nor all possible faults described, the following discussion is intended as an aid in perfecting your troubleshooting technique.

Before attempting any job, the area to be used for effecting the repair should be thoroughly prepared, so that the job may be done quickly and efficiently. One thing you should keep in mind when replacing a defective part—be sure that that part is installed correctly and in its proper place. If this rule is not followed it may cause much trouble for the man that relieves you. Always use a systematic approach when troubleshooting; never repair by hunches. Become thoroughly familiar with the schematic and wiring diagrams, then go to work.

While becoming familiar with the schematic and wiring diagrams, develop your planning so as to check the easy and obvious things first (preliminary check). For example, the I.C. Electrician takes notes of all meter readings, fuse indications, smoke, and odor while obtaining information from the operator concerning the failure. He makes a careful examination of the equipment for loose tubes, burned or charred parts (indicates a possible defective part), loose or irregular conditions existing on or near switches, connections, and so on. If possible, he tries to determine whether the trouble developed suddenly, or whether it was a gradually progressive fault. Further, it is helpful to know whether the trouble is intermittent or of a continuous nature.

At this time, check the equipment history cards for symptoms that match the failure. If the records have been kept correctly and are current, there is a good chance of the symptoms being matched with a past failure, and an immediate repair can be effected. The importance of adequate records and reports cannot be too highly stressed because their use will save many hours by eliminating troubleshooting procedures previously performed.

If burned or charred parts are found, a thorough examination of all the circuitry must be made before installing replacement parts, and before energizing the equipment. Merely replacing a bad fuse or part and then energizing the equipment could result in a major defect developing from the renewal surge current. An important fact to keep in mind is that replacement parts are limited when a ship is at sea. Therefore, careless substitution may take all of your ready repair parts, without accomplishing the repair so that the equipments may be placed back in service.

After completing the preliminary check without making the repair, follow the detailed troubleshooting procedure set forth in the instruction manual.

The detailed method of troubleshooting involves the taking of resistance, voltage, and current measurements. Very difficult faults may need additional information before repairs can be made and such information may be obtained by taking waveforms, or power measurements. Interpretation of the measurements taken will determine where the fault lies. By a process of elimination the fault can then be isolated to a given stage, and to a given part.

Let us illustrate a systematic detailed method of troubleshooting by assuming a failure has developed in the intercommunicating unit (fig. 5-9).

Assume that the failure involves a situation where the equipment is still operating but has developed a slightly distorted and low output (gain control at maximum to be heard). There are many parts that can cause this type of indication, therefore, we must track down and

isolate the indicated trouble to one particular stage and then to the particular part.

One very useful and quick method used to pinpoint a trouble is by using a signal generator and oscilloscope. With the signal generator supplying the amplifier input with a sine waveform sample the inputs and outputs for a comparison test. Starting from the speaker (output end) and working back (to the input end) stage by stage, you can determine where the distortion signal begins by simply observing the waveform at each check point. For low output, you will compare the signal strength, between points. The fault can then be isolated between two stages by comparing the signals prior to and out of any given stage. For example, a plate output being slightly distorted as compared to the undistorted input grid signal.

We have assumed that the equipment functions to some extent but in order to be heard, it must be operated with the gain control at maximum. If for any reason the equipment must be turned off, then the trouble must be located by some other method, for instance, by a resistance test. Regardless of the method used, the problem is one of determining where the difference in the signal occurs, and isolating it to its particular part or parts.

With the equipment operating at normal, except that now the gain control must be at maximum, begin with the oscilloscope test. Remember that for this test an ideal output should be a clear, well defined reproduction of the signal waveform introduced at the equipment input with the gain control near its midposition. Any difference from this ideal output must be considered as a fault.

Because transformers and speaker coils are seldom found to be at fault and because in our example there is an output, we will take our first test at the plates of V3 and V4 (fig. 5-9) to ground. Bypass capacitor C9 connected effectively between ground and the center tap of T2, terminal 2, permits measuring the a-c signal developed across each section of T2 to ground. Therefore, the output signals tested will normally be an amplification of their respective grid input signals.

Assume the test of V3 to ground is normal, and V4 to ground is distorted with a slight reduction in signal strength. If the signal were to be tested at T2, terminals 1-3, the signal would contain the same distortion as the T2 secondary output to the speaker. This output is the sum of the outputs developed from the V3 and V4 plates as measured at terminals 1-3, T2, and is the coupled signal to the T2 secondary to the speaker.

These tests show that the circuitry leading up to V3 is normal and needs no further checking, while V4 indicates that the trouble is present somewhere forward. Similar checks of the V4 grid input and V2B plate reveal a weaker but still distorted output. A check of the V2B grid indicates that the signal differs from the signal at the V1B plate. Therefore, we can consider our fault isolated to a given stage (V2B) and all we have to do now is locate the bad part or parts.

In order to locate the part at fault we now change our oscilloscope for a multimeter and take voltage measurements (the equipment is still operating). Use any suitable multimeter or VTVM available.

First, set the meter on d-c volts, and using the 300 volt scale, measure the d-c voltage between the V1B plate and ground. The measured value is below normal. Now let us reason out what could cause this reduction in reading. We have already eliminated V1 because it permits a good signal to appear at the plate. This leaves two other possibilities: (1) the power supply, and (2) the coupling circuit to the grid of V2B. The power supply can be eliminated because trouble here would affect all the other stages. Therefore, the coupling circuit must contain the fault, and we can now make a voltage test at the V2B grid to ground. Normally, a grid to ground is either zero or slightly negative.

The V2B grid to ground measures a relatively high positive d-c voltage, so we are now in the guilty circuit. Resistance measurements are the best way to determine changes in the characteristics of individual parts, so we again change our method of test. Turn the equipment power off and take resistance measurements of the grid coupling circuit which includes R5, R11, and C2. Note that R12 appears to be in the circuit, but in the operate position is short circuited to ground via J6, terminal D, to the handset back to terminal C (chassis ground).

The resistance measurement across C2 (with one end of C2 disconnected from the circuit) measures approximately 200 K. Capacitors are considered bad if the d-c resistance value drops below 50 megohms. Our trouble is a leaky capacitor.

A description of the probable effects of a leaky capacitor match our fault so we know that replacing C2 will repair the equipment for service. This is caused by increased current through R2. (The drop across R2 subtracts from the B supply voltage.) Also, the current which now flows up from ground through R5 and R11 causes a positive voltage on the V2B grid and this voltage results in limiting (distortion) due to the grid current flowing on portions of the input signal.

Let us suppose, for explanation purposes, that the capacitor had been open instead of leaky.

Theoretically, capacitors should read infinity for d-c resistance measurements. Actually, because of the manufacturing limitations, this is not possible and therefore resistance values of 50 megohms and higher are considered good. Anything below these values is suspect. So! How do we know for sure if the capacitor is good or bad?

Two simple on-the-job methods can be used. First, using the highest ohm scale on the multimeter, apply the test prods across the capacitor (one end of the capacitor must be disconnected from the circuit) and at the same time watch the meter indicator action for changes. If the pointer dips and then moves back up scale to a high megohm reading, it indicates a charging current through the meter resistance to the capacitor, and the capacitor is good.

The second method uses any d-c source available and is a method of obtaining additional assurance when the first method does not satisfy. Apply the voltage of the d-c source across the circuit capacitor leads. The capacitor (disconnected from the circuit) will charge up to the d-c voltage value and hold this charge for a while. Remove the source from the capacitor and connect the headphones across the capacitor leads. If the capacitor is good, a click will be heard in the headphones indicating a discharging current.

The preceding tests are examples of the various methods needed to locate a specific trouble. It would be well to remember that in troubleshooting, the methods that locate the failure in the shortest possible time with the least number of steps is the best method, and beginning with the easiest method first, several methods may be needed before the faulty part is located.

When trouble is encountered, the three tests commonly used are voltage, current, and resistance. When the equipment can be operated, a voltage test is the quickest way to pinpoint the trouble. Continuity tests must be used when the equipment blows fuses, or is inoperable. Usually, current tests are used when there is a need to adjust equipment to obtain maximum or peak performance.

MAINTENANCE

A test fixture is provided with the maintenance parts of the equipment to facilitate testing the intercom units. The test fixture is housed in a metal case and includes the necessary switches, resistors, and controls to perform all essential tests on a unit. It is provided with a line cord and plug for connection to the ship's 115-volt 60-cycle power supply, and suitable female connectors for attaching it to the rear of the unit under test. The front cover contains 11 DPDT test switches, S201 through S211, a SPST call lamp test switch, S212, a SPST talk test switch, S213, a DPDT polarity test switch, S214, and an indicator lamp, I201 (fig. 5-13).

To use the test fixture, remove the intercom unit to be tested from its case and attach the test fixture to the rear of the unit by plugging it into the unit and connecting the line cord and plug to the ship's 115-volt 60-cycle power. On the test fixture (fig. 5-13), operate the talk switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test (fig. 5-8), depress the release pushbutton, S1, turn the volume control, S25, and dimmer control, S27, to the extreme clockwise positions, and connect a microphone or handset into the microphone jack, J6 (fig. 5-8).

Polarity Test

To test the polarity of the unit, operate the polarity test switch, S214 (fig. 5-13), to the OK WHEN LIT position (not shown). The indicator lamp, I210, should light with full intensity if the polarity is correct. Now operate the polarity test switch, S214, to the REVERSED position (not shown). The indicator lamp should go out if the polarity is not correct. The lamp may glow faintly but it is not important. The polarity test checks the polarity of the line and signal voltage windings (terminals 10-11 and 8-9 respectively) of the power transformer, T3 (fig. 5-9).

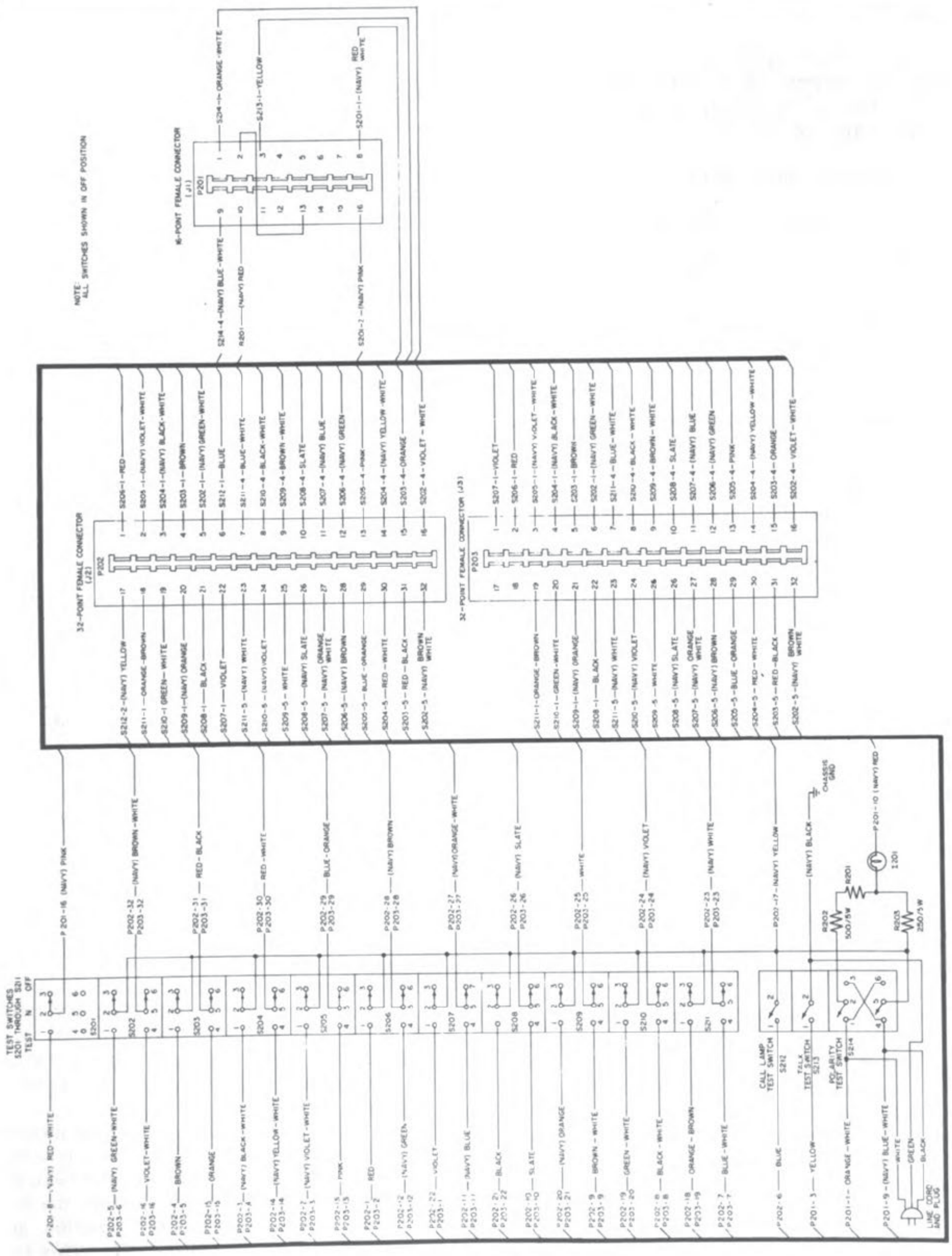

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Figure 5-13.—Wiring diagram of text failure.

Call Lamp Test

To test the call lamp of the unit, operate the call lamp test switch, S212, on the test fixture (fig. 5-13). The call lamp, I2, on the unit under test should be lighted (fig. 5-8).

Amplifier and Reproducer Test

To test the amplifier and reproducer, depress the (microphone) talk switch and talk into the microphone. The talker should hear his voice clearly through the reproducer. Rotate the volume control knob, S25, on the unit under test (fig. 5-8) while talking into the microphone, and observe the effect on the output volume. Now place the microphone close to the reproducer. A microphonic feedback should be observed when the volume control is in the full-volume position as well as at one step below full volume. This test provides a rough indication of the amplifier gain, power output, and the general performance of the entire unit, except for the signaling circuits.

Station Selector Circuit Test

On the test fixture (fig. 5-13), operate the talk test switch, S213, to the TALK position with the microphone reasonably close to the reproducer to produce a microphonic howl. Reduce the volume control to the minimum position at which the howl can still be obtained by moving the microphone as close to the reproducer as required. This position will produce the minimum objectionable howl during the subsequent station selector circuit tests.

On the test fixture, operate the test switch, S210, to the TEST position which should stop the microphonic howl. Then restore S210 to the STANDBY position. This test checks the circuit from terminals 1 and 1C, through the busy relay, K2, (not operated) to the line winding terminals 14 and 15 of the output transformer, T2 (fig. 5-9). When test switch, S201, is in the TEST position, it places a short circuit across terminals 1 and 1C to interrupt the microphonic howl.

On the unit under test (fig. 5-8), depress the station selector pushbutton, S2 (adjacent to release pushbutton S1). On the test fixture (fig. 5-13), operate the test switch, S202, to the TEST position which should interrupt the microphonic howl. Then restore S202 to the STANDBY position and depress the release pushbutton, S1, on the unit under test. This test checks the continuity between terminals 2 and 2C (fig. 5-9) through switch S2U and busy relay K2 to the line winding terminals 14 and 15 of transformer T2.

Similarly, on the unit under test (fig. 5-8), depress the remaining station selector pushbuttons S3 through S11, using the corresponding test switches, S203 through S211, on the test fixture (fig. 5-13) for each test. This test checks the continuity of the various audio circuits. If the unit under test is provided with facilities for originating calls to 20 stations, repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

Signal Circuit Test

On the test fixture (fig. 5-13), operate the talk test switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test (fig. 5-8), depress the release pushbutton, S1, for the subsequent signal circuit tests.

On the test fixture, operate test switch, S202, to the TEST position and on the unit under test, depress the station selector pushbutton, S2. The busy lamp, I1, should light. On the unit under test, depress the release pushbutton, S1, and again depress the station selector switch, S2. The busy lamp, I1, should go out and again light. Repeat this test several times in rapid succession. On the test fixture, restore test switch, S201, to the standby position and on the unit under test, depress the release pushbutton, S1.

When the test switch, S202, on the test fixture is operated to the TEST position, it makes station 2 busy by connecting terminal 2X to terminal XX (fig. 5-9). When the station selector pushbutton, S2, on the unit under test is depressed to select station 2, it checks the busy circuit through the lower switch assembly, S2L, busy relay, K2, latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch assembly, S2U, and associated wiring.

On the test fixture, operate the test switch, S203, to the TEST position and on the unit under test, depress the station selector pushbutton, S3. The busy lamp I1 should light. Restore the test switch, S203, to the STANDBY position and depress the release pushbutton, S1. This test

checks the operation of the busy relay, K2, the lower switch assembly, S3L, the latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch section, S3U, and associated wiring.

Test the remaining pushbuttons by operating first the test switches, S204 through S211, to the TEST position on the test fixture and then depressing the corresponding station selector pushbuttons S4 through S11, on the unit under test. If the unit under test is a 20-station type repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

The manufacturer's technical manual furnished with the equipment installed in your ship contains more detailed information concerning the operation, repair, and maintenance of intercommunicating units.

QUIZ

1. What is the purpose of shipboard announcing and intercommunicating circuits 1MC through 34MC?
2. Name the two systems which accomplish the purpose of question 1.
3. When is a (1) central amplifier, and (2) intercommunicating system employed?
4. Name the two kinds of amplified signals furnished by a central amplifier announcing system.
5. Name the four alarm signals in the order of their priority described in the 1MC-6MC central amplifier announcing system.
6. Are alarm signals transmitted over all 1MC and 6MC loudspeakers or only over the 1MC or 6MC loudspeakers?
7. Which of the four microphone control stations can select any one or more of the four 1MC loudspeaker groups or the circuit 6MC loudspeakers?
8. Does circuit 1MC or circuit 6MC have priority control over all microphone stations?
9. What is the purpose of the oscillator assemblies?
10. What is the purpose of the preamplifier?
11. What is the purpose of the power amplifiers?
12. How many amplifier channels are provided in the 1MC-6MC announcing system?
13. Why is the voltage applied to the control grids of V5A and V6A 180 degrees out-of-phase with that applied to the control grids of V5B and V6B (fig. 5-5)?
14. How is the signal voltage, which is applied to the grids of the power amplifier, V5A and V6A, by potentiometer, R15, applied to the compressor circuit in the preamplifier (fig. 5-5)?
15. How is the output voltage from the plates of V11A and V12A coupled to the voltage amplifier, V9 and V10 (fig. 5-5)?
16. How is the output voltage from the cathodes of V11A and V12A coupled to the voltage amplifier, V9 and V10 (fig. 5-5)?
17. What is the result of the diode sections of V7 and V8 conducting alternately when the signal voltage applied to the cathodes of V7 and V8 is greater than the bias voltage (fig. 5-5)?
18. (a) When is the voltage thus produced (question 17) applied, and (b) for what purpose (fig. 5-5)?
19. What action occurs with respect to the conduction of V7 and V8 when the compressor switch, S1, is closed to connect a smaller negative operating bias voltage to the bias line and the amplifier gain increases because the bias on the grids (pin 7) of V1 and V2 is made less negative (fig. 5-5)?
20. How is the output of the phase-inversion stage, V15B and V16B, coupled to the driver tubes, V17B and V18B, in the power amplifier (fig. 5-6)?
21. What is the purpose of the tertiary winding (8-9) on the output transformer, T6, of the power amplifier (fig. 5-6)?
22. What action occurs when relay, K106, closes and grounds the cathodes of the phase-shift oscillator section, V35B and V36B (fig. 5-7)?
23. How is the output of V35B and V36B fed to the voltage amplifier stage, V33 and V34 (fig. 5-7)?

24. What is the function of the collision alarm contactor?

25. How is the signal through V33 and V34 cut off by relay, K105, when general alarm is being sounded (fig. 5-7)?

26. How is the gradual reduction of the signal transmission through V33 and V34 accomplished (fig. 5-7)?

27. How is amplfication of the general alarm signal accomplished (fig. 5-7)?

28. What two functions are performed by relay, K104, which is energized by relay, K108, when the sonar alarm relay is operated (fig. 5-7)?

29. What other function is accomplished by the closure of relay, K108, with respect to the 1 1/2 cps oscillator, V29A and V30A (fig. 5-7)?

30. What is the function of the 1 1/2 cps multibrator oscillator, V29 and V30?

31. What condition is indicated when busy 1 lamp is lighted at a circuit 1MC microphone control station?

32. What condition is indicated when busy 2 lamp is lighted at a circuit 1MC microphone control station?

33. What condition is indicated when busy 1 lamp is lighted at the circuit 1MC-6MC microphone control station?

34. What is the condition of the busy 1 and busy 2 indicators at the microphone control stations when an alarm is sounded?

35. How can a defective microphone control station, which prevents normal operation from other microphone control stations be isolated?

36. How can a defective loudspeaker, which results in a lower than normal meter reading of the power amplifier output, be located?

37. (a) From what source is the test signal obtained, and (b) how is it applied to preamplifier when testing for normal preamplifier operation (fig. 5-5)?

38. How are the meter switch, S2, and the output meter, M1, used to obtain output readings of the various stages of the preamplifier (fig. 5-5)?

39. (a) From what source is the test signal obtained; and (b) how is it applied to a power amplifier when testing for normal power amplifier operation (fig. 5-6)?

40. How are the meter switch, S3, and the output meter, M2, used to obtain output readings of the various stages of the power amplifier (fig. 5-6)?

41. How is each stage of an oscillator tested for normal operation (fig. 5-7)?

42. What facilities are provided in the two types of intercommunicating units with respect to originating calls to other stations?

43. Name the three principal components of an intercom unit.

44. What dual purpose does the reproducer serve?

45. Where is the incoming call to an intercom unit amplified?

46. What is the purpose of the press-to-talk switch?

47. Under what condition is the busy lamp lighted at an intercom unit?

48. What signal is controlled by the volume control of an intercom unit?

49. What is the purpose of the primary taps on the input transformer, T1, of the amplifier (fig. 5-9)?

50. What purpose does the output transformer, T2, serve when the intercom unit is receiving calls and the amplifier is not in use (fig. 5-9)?

51. What is the normal connection of the audio lines from terminal 14 of transformer, T2, (fig. 5-10)?

52. What is the normal connection of the audio lines from terminal 15 of transformer, T2, (fig. 5-10)?

53. Trace the incoming signal, which appears across terminal 7 of T2 and the moving contact of the volume control, S25, at station 3 through terminal 7 of T2 at station 3A (fig. 5-11).

54. If the talk relay, K1, is operated at either station 3 or 3A, what effect does it have on the input to the audio circuit of stations 3 and 3A (fig. 5-11)?

55. When using the test fixture to test the polarity of an intercom unit, what is the condition of the indicator lamp, I201, if the polarity is correct when the polarity test switch, S214, is operated to the OK WHEN LIT POSITION (fig. 5-12)?
56. What switch on the test fixture must be operated to the ON position to produce a microphonic howl with the portable microphone reasonably close to the reproducer prior to making station selector circuit tests (fig. 5-12)?
57. Will the microphonic howl continue if the audio circuit of station 2 checks for proper continuity when pushbutton S2 is depressed (on the unit under test) and test switch, S202, is operated to the test position (on the test fixture)?
58. Will the busy lamp, I1, light if the signal circuit of station 2 checks for proper continuity when the release pushbutton, S1, and then the station selector pushbutton, S2 (on the unit under test), and test switch, S202, are operated to the test position (on the test fixture)?

CHAPTER 6

SUPPLEMENTARY COMMUNICATION EQUIPMENT

SOUND-POWERED TELEPHONE AMPLIFIER SYSTEM

The sound-powered telephone amplifier provides a method of amplifying one-way communication (incoming speech) in a two-way sound-powered telephone communication system. The equipment is designed to amplify voice signals so that the reproduced message will be clear and understandable at locations aboard ship where the noise level is high (gun positions or machinery spaces). When the amplifier is turned off, the system functions normally for two-way communication at the sound-powered level.

A sound-powered telephone amplifier circuit consists of an amplifier, one to six sound-powered telephone headsets, and one or two loudspeakers. A sound-powered telephone amplifier system consists of one or more sound-powered telephone amplifier circuits connected to the ship's soundpowered telephone lines and to the ship's 115-volt 60-cycle power supply (fig. 6-1). For simplicity, only one headset and and one loudspeaker are shown in each amplifier

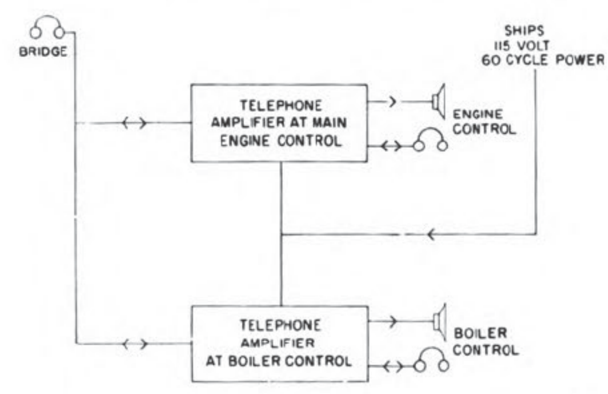

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Figure 6-1.—Block diagram of sound-powered telephone amplifier system.

circuit. Each amplifier supplies voice signals to the local headsets and loudspeakers at the associated machinery spaces.

TELEPHONE AMPLIFIER

The telephone amplifier (fig. 6-2) consists of a metal enclosure designed for bulkhead mounting and a plug-in panel chassis assembly.

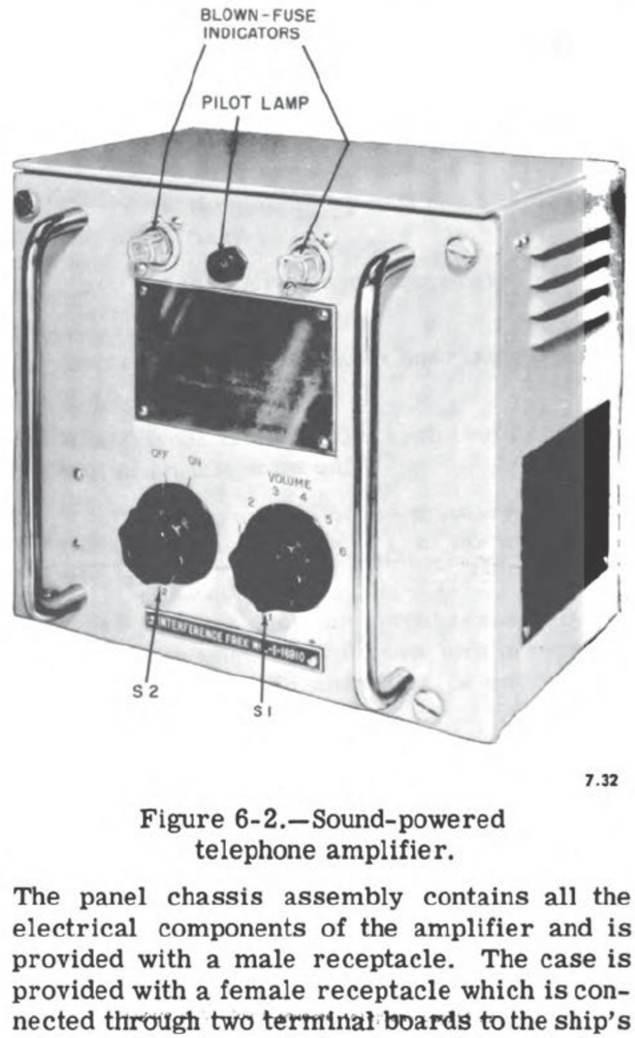

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Figure 6-2.—Sound-powered telephone amplifier.

The panel chassis assembly contains all the electrical components of the amplifier and is provided with a male receptacle. The case is provided with a female receptacle which is connected through two terminal boards to the ship's wiring. The plug-in feature completes all electrical connections between the panel chassis assembly and cabinet wiring. The front panel of the chassis assembly contains the on-off switch S2, the volume control S1, a pilot lamp, and two blown-fuse indicators.

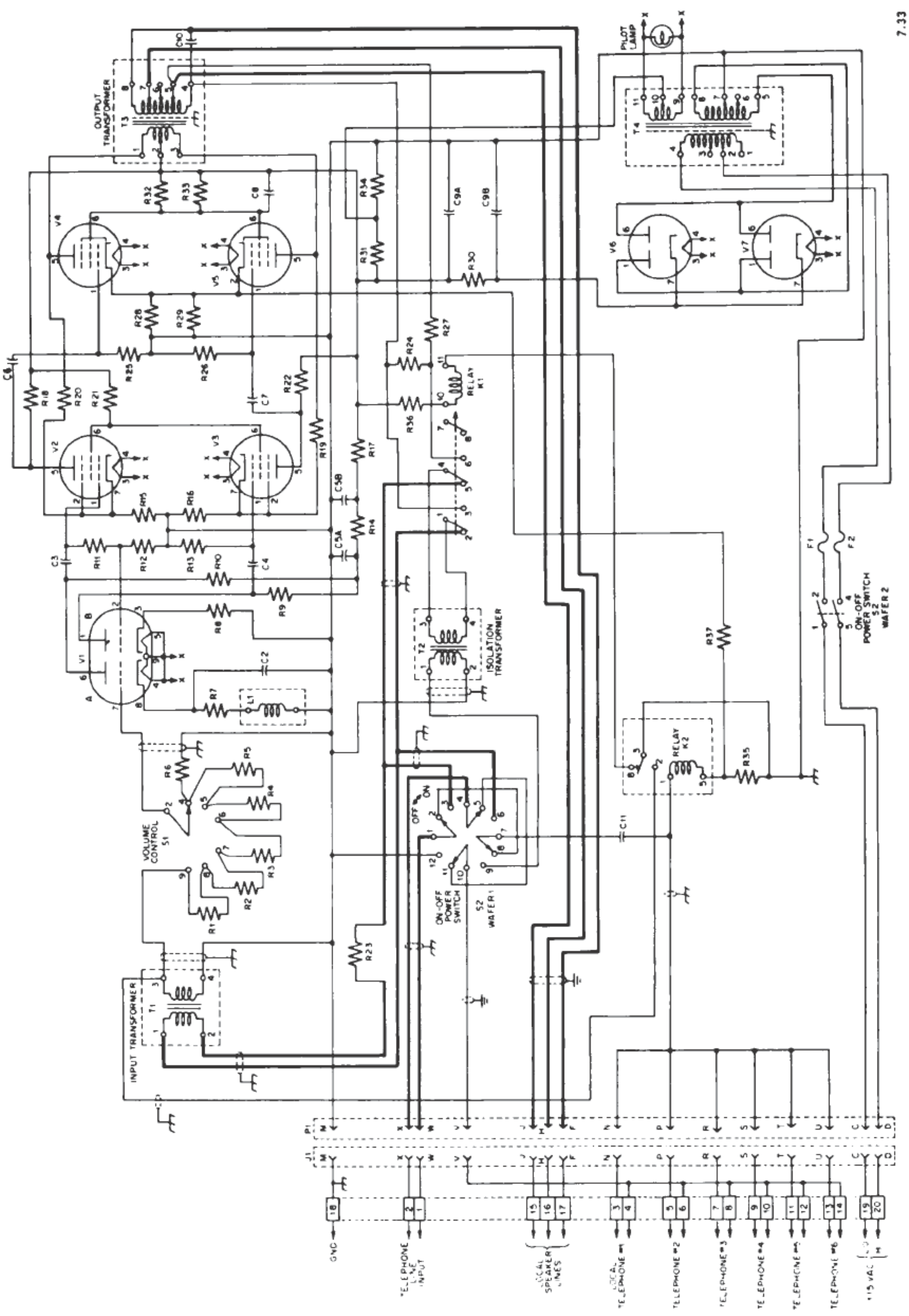

Figure 6-3.—Schematic diagram of sound-powered telephone amplifier.

A schematic diagram of the telephone amplifier is illustrated in figure 6-3. The amplifier is a three-stage resistance-capacitance coupled unit. The signal received from the sound-powered telephone line (terminals 1-2) is applied to the primary of the input transformer T1 via contacts 3 and 6 of S2 wafer 1. The secondary of T1 is connected via the volume control S1 to the grid of section V1A operating as a voltage amplifier. Section V1B is a phase inverter. The filter choke L1 in the cathode circuit of the voltage amplifier stage V1A compensates for the sharp-peak response characteristics of sound-powered telephone transmitters.

The outputs of V1A and V1B drive V2 and V3 respectively, operating as a push-pull voltage amplifier. The outputs of V2 and V3 drive V4 and V5 respectively, as a push-pull power amplifier. The output of the power stage is applied to the primary of the output transformer T3, the secondary of which is connected to the local headsets and loudspeakers.

The parallel-connected full-wave rectifiers V6 and V7 supply d-c potentials for the plates and grids of all amplifier tubes. The pulsating d-c output of the rectifiers is filtered by the capacitor-resistor network consisting of C9B, R30, and C9A.

The sound output level of the amplifier to both the local headsets and loudspeakers is controlled by the volume control S1, comprising resistors R1 through R6 as a voltage divider between T1 and V1A. An additional gain control mounted on each loudspeaker may be used to control the loudspeaker volume. The volume of the headsets is determined by the connections to the output transformer T3.

OPERATION

The methods of operating the sound powered telephone amplifier system depend on the position of the on-off power switch S2, and the availability of the ship's 115-volt 60-cycle power at the amplifier (fig. 6-3).

When the on-off power switch S2 is in the OFF position, (shown in figs. 6-3 and 6-4) sound-powered telephones are connected directly to the telephone line and the system functions as a two-way communication circuit between the local sound-powered telephone stations and the remote station at the sound-powered telephone level.

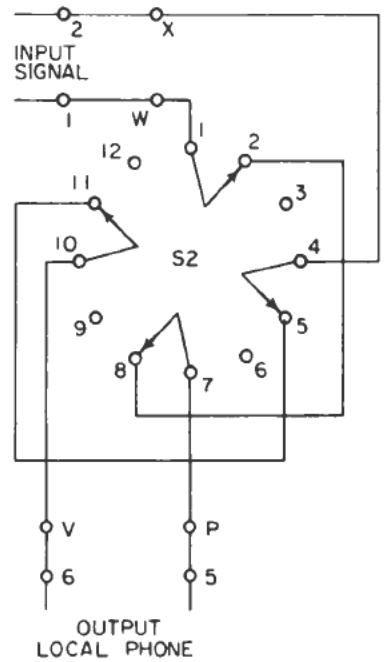

Figure 6-4.—Modified schematic diagram of sound-powered amplifier circuit for incoming calls with S2 "OFF."

When it is desired to amplify the incoming speech at the local stations (fig. 6-5), operate the on-off power switch S2 to the ON position. A-c power is applied to the amplifier through wafer 2 of switch S2 (not shown); the telephone line input is connected to the 1-2 winding of transformer T1, through contacts 1-3 and 4-6 of switch S2 wafer 1; the local telephones are connected to the 1-2 winding of the isolation transformer T2, through contacts 7-9 and 10-12 of switch S2; and relay K1, which is energized when a-c power is applied to the amplifier, operates to connect the output transformer T3 to the 3-4 winding of the isolation transformer T2. Thus the incoming signals on the telephone line are amplified and reproduced by the headsets and loudspeakers connected to T3.

When it is desired to transmit speech over the local headset (fig 6-6) operate the talk switch (not shown) on the transmitter. The local loudspeaker will be cut and speech goes out to the other local headsets and over the sound-powered telephone line at the sound-powered telephone level.

If the power switch S2 is in the ON position when the transmitter talk switch is operated at

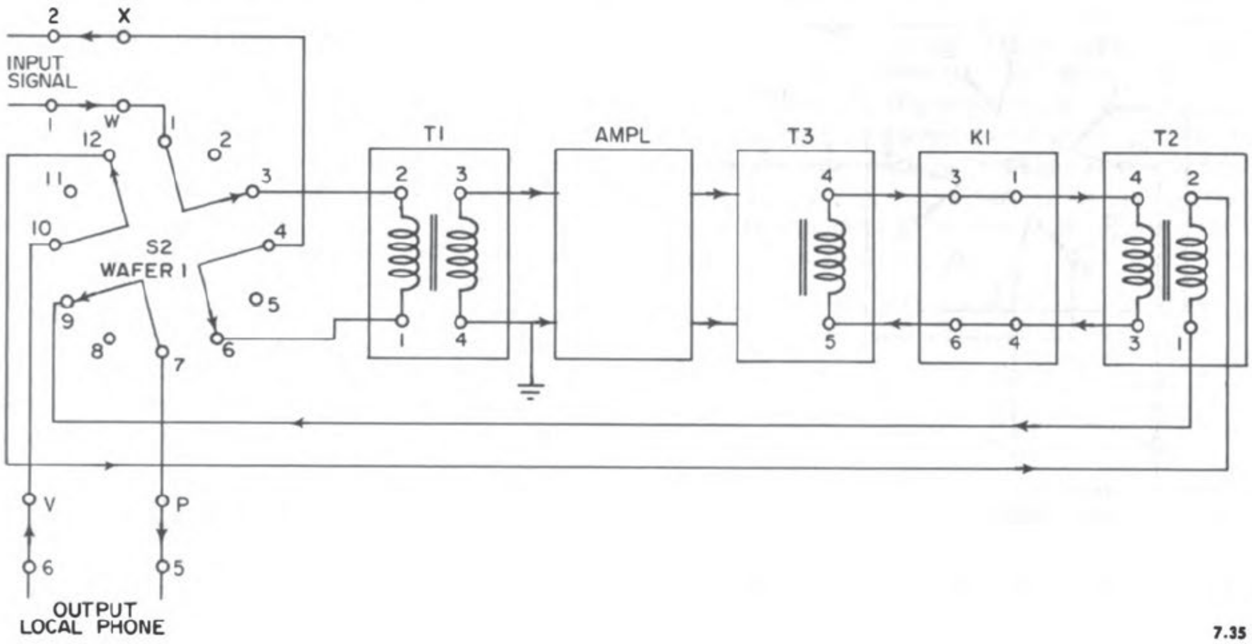

Figure 6-5.—Modified schematic diagram of sound-powered amplifier circuit for incoming calls with S2 "ON."

the local headset, a-c power is applied to the amplifier through wafer 2 of switch S2. Relay K2 is energized when the local telephone talk switch is operated to complete the circuit between terminal V and N, P, R, S, T, or U of plug P1 (fig. 6-3), depending on which telephone talk switch is operated. The talk switch completes a circuit between the low impedance transmitter (not shown) and the two telephone lines. This action effectively places K2 across R35 to operate the relay with a portion of the cathode currents of V4 and V5. Capacitor C11 prevents d-c from flowing in the primary of T2. Relay K2 grounds the amplifier input at the secondary of the input transformer T1 and deenergizes relay K1 which operates to connect the telephone line to the 3-4 winding of T2 and to bypass the amplifier. Thus, the local telephones are connected to the primary of T2 through contacts 7-9 and 10-12 of switch S2 and speech into the transmitter (talk switch operated) goes out over the telephone line at the sound-powered telephone level. The local headsets at their respective stations also hear the speech at the sound-powered telephone level. Figure 6-7 shows the talk circuit for calls originated at a local headset when S2 is in the OFF position.

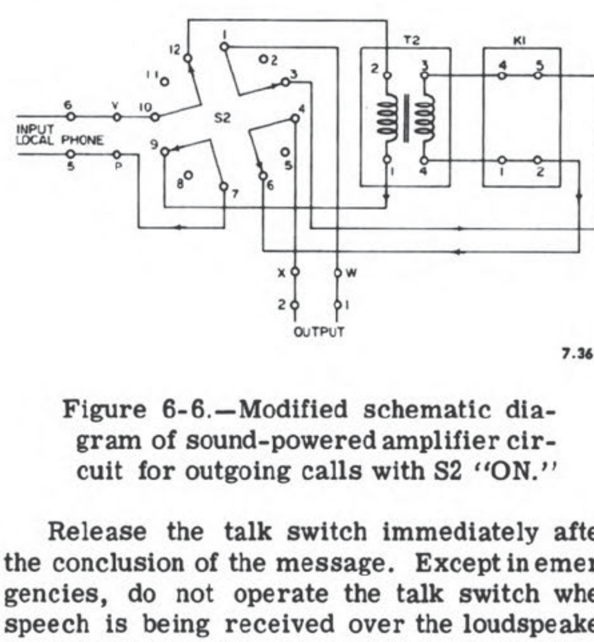

Figure 6-6.—Modified schematic diagram of sound-powered amplifier circuit for outgoing calls with S2 "ON."

Release the talk switch immediately after the conclusion of the message. Except in emergencies, do not operate the talk switch when speech is being received over the loudspeaker because it cuts off the amplifier and the loudspeaker. The voice is heard on the local headsets but only at the sound-powered telephone level.

When the on-off power switch S2 is in the ON position and a-c power is not applied to the

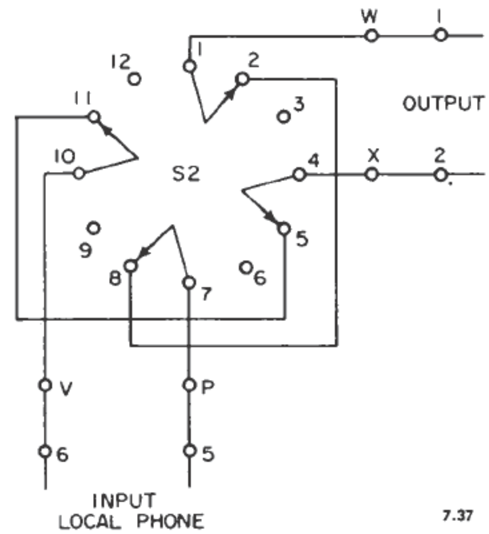

Figure 6-7.—Modified schematic diagram of sound powered amplifier circuit for outgoing calls with S2 "OFF."

amplifier because of power failure or a blown fuse, relay K1 is not energized, the telephone line remains connected to the 3-4 winding of T2, and the local telephone is connected to the 1-2 winding of T2. Thus, the amplifier is bypassed and the system functions as a normal (unamplified) sound-powered telephone circuit.

The amount of light from the pilot lamp can be dimmed or cut off completely by rotating the lamp cap in the clockwise direction.

MAINTENANCE

Operational tests usually indicate the general location of trouble in the sound-powered telephone amplifier. Before attempting amplifier troubleshooting procedures deenergize the equipment.

Operate the talk switch at the local telephone and talk to the other local telephones. Carry on a two-way conversation at the sound-powered telephone level. If the connection is not satisfactory, check the telephone wiring and the telephones.

Operate the talk switch at the local telephone and talk to the remote telephone. Carry on a two way conversation at the sound-powered level. If the connection is not satisfactory, check the remote telephone, the wiring, and the amplifier switch S2.

Turn the amplifier switch S2 to the ON position. The pilot lamp lights to indicate when power is applied to the amplifier. If the lamp does not light, check the blown-fuse indicators, check the pilot lamp by replacing it with a new one, and check the a-c power to the amplifier.

Operate the talk switch at the local telephone and speak into the microphone. The voice should be heard at the other local telephones and at the remote telephone at the sound-powered level, but not over the local loudspeaker. If voice is not heard, check the talk switch, relay K2 and relay K1 (fig. 6-3).

Operate the talk switch at the remote telephone and speak into the microphone. The voice should be heard over the local loudspeaker and over the local headsets at the amplifier level. If the voice is not heard from the local headsets, check the talk switch, amplifier, relay K1, and relay K2. If the voice is not heard from the loudspeaker, check the loudspeaker.

Troubleshooting on an inactive amplifier is accomplished by taking resistance measurements, voltage measurements, or signal tracing. If the amplifier is blowing fuses, the voltage and signal tracing methods cannot be used and the amplifier must be checked by making resistance measurements.

Before conducting any tests remove the amplifier from the enclosure and disconnect it from all external circuits. Insert a plug in the receptacle in the enclosure while the amplifier chassis is not connected to, or inserted in, the enclosure case to maintain communication between the local and remote telephone stations at the sound-powered level. The plug is the same as P1 (fig. 6-3) with terminals N, P, R, S, T, U, and X connected and terminals W and V connected.

Signal Tracing

Signal tracing helps to localize troubles to a particular stage of the amplifier. An externally generated signal from an audio oscillator is applied to the input of the amplifier and the signal voltage is measured at the grid and plate of each tube.

An audio oscillator capable of delivering a 1,000 cps signal at 12 millivolts and an a-c voltmeter section of a VTVM capable of reading 12 millivolts to 155 volts are required. Connect the 115-volt 60-cycle power to terminals C and

D of the input connector J1 (fig. 6-3), with the amplifier removed from the enclosure. Apply the 1,000 cps signal at 12 millivolts to terminals X and W of the input connector. Operate the on-off power switch S2 to the ON position and turn the volume control S1, clockwise to position 6. Allow about one minute for the tubes to reach operating temperature. Using the a-c voltmeter with the low side of the meter connected to the amplifier chassis, compare the readings obtained at the grid and plate of each tube with those listed in the technical manual. Normal operation is indicated if the readings agree within 10 percent. Start with tube V1A and check each stage in order. If the measured voltage is low, use further isolating techniques to determine the defective part within the stage.

Component Tests

Check the tubes that are suspected of being weak or otherwise defective with a tube tester. A tube that is defective because of internally shorted electrodes may affect the operation to the extent that voltage and resistance readings will be abnormal. The absence of filament glow in a tube indicates an open filament.

RESISTORS that are defective can be detected in several ways. A resistor that has been overloaded will often become discolored and give off noticeable odors. Ohmmeter readings across a resistor (with the power off) will indicate a resistor that is open or if its value has changed. When checking the values of resistors with an ohmmeter, determine if other components directly associated in the circuit will affect the readings. In some cases it may be desirable to disconnect one end of the resistor when making resistance checks.

With the power on, voltage readings can be compared with those listed in the technical manual. Overloaded resistors are often caused by defective capacitors. Check the capacitors in the circuit before restoring power to the amplifier.

CAPACITORS that are short-circuited are indicated by a zero ohmmeter reading. An ohmmeter reading of infinity will be obtained on a paper capacitor if the capacitor is good, or if it has a broken internal lead. A lower value will be obtained on an electrolytic capacitor which leaks. Temporarily replace a paper capacitor that gives an ohmmeter reading of infinity and that is suspected of being defective with one that is known to be good and note the effects on the voltage checks and operation. If the trouble is corrected after the replacement, the capacitor is defective and should be permanently replaced.

When testing the electrolytic capacitor C9 (removed from its socket) set the ohmmeter to a medium range and connect it to the capacitor with the correct polarity (common to negative and positive to positive). A deflection will occur on the meter and the pointer will return slowly toward the infinite-ohms position as the capacitor takes a charge. Usually, some reading is obtained even when the electrolytic capacitor is fully charged. If C9 is good, the final ohmmeter reading will be over 500,000 ohms for each section (C9A and C9B).

PUBLIC ADDRESS SET

The public address set is a portable voice projection system designed to amplify and transmit intelligible speech over extended distances through high ambient noise levels. It is particularly useful for: (1) issuing orders from the bridge to personnel at topside stations; (2) communicating between ships when fueling or taking on stores at sea; and (3) communicating to and from tugs while maneuvering and docking.

The electric megaphone itself is similar in appearance and use to an ordinary megaphone, but has the advantage of greater range and intelligibility. The output, and hence the range, of the electric megaphone can be increased by the use of a remote microphone.

CONSTRUCTION

The public address set (fig 6-8) consists of an electric megaphone (loudspeaker-microphone), a remote microphone, and an audio amplifier.

Electric Megaphone

The electric megaphone comprises a permanent magnet dynamic loudspeaker and a magnetic

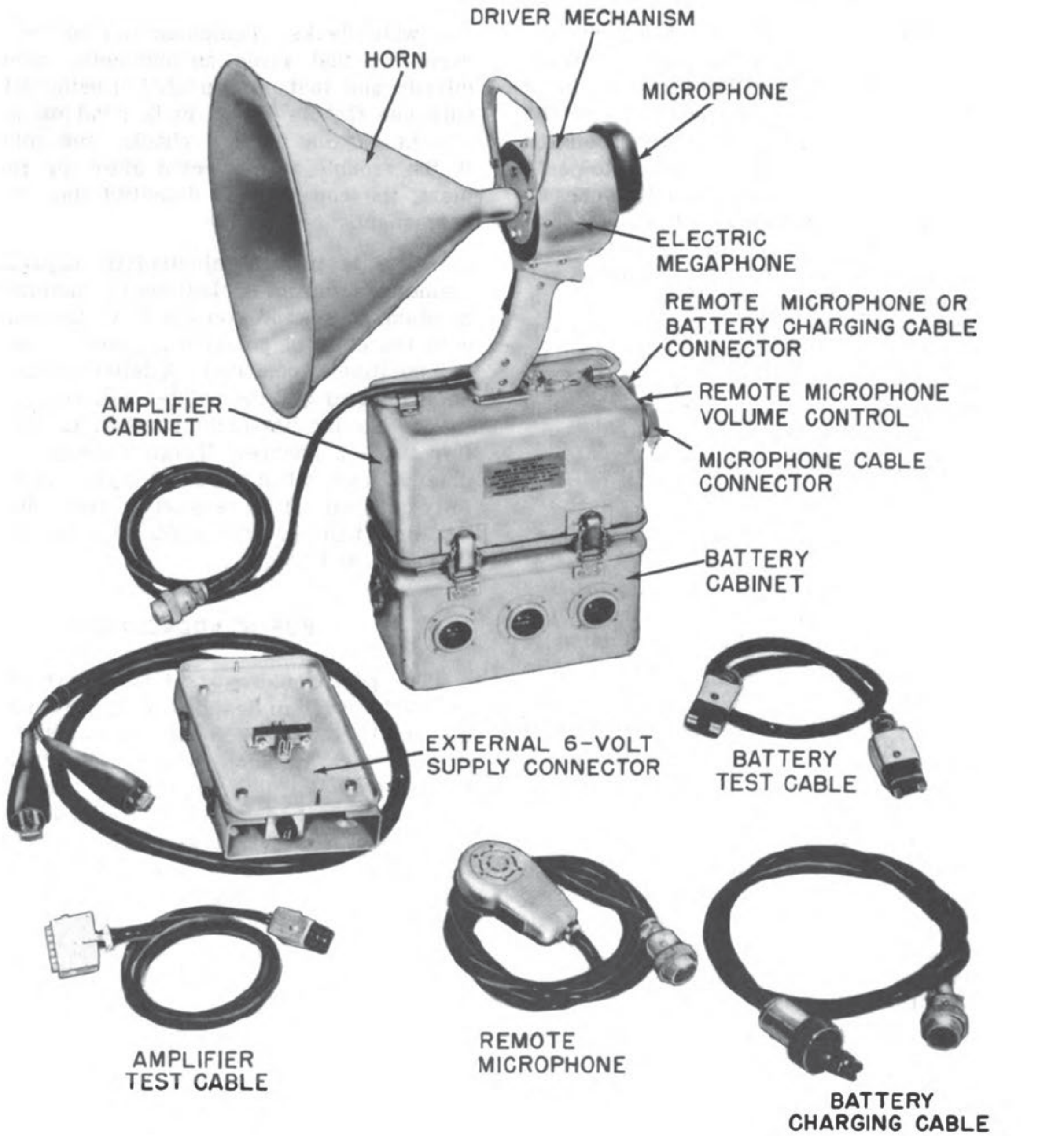

Figure 6-8.—Public address set.

microphone. The microphone is mounted at the rear of the loudspeaker housing and is provided with a volume control to determine the amplitude of the input signal to the amplifier.

The megaphone unit is supported on an operating handle, the base of which can be secured to a bracket on top of the amplifier case so that both units can be transported by a carrying handle attached to the megaphone unit. The operating handle is used to direct the megaphone and contains a microswitch and a trigger-type pushbutton to energize the amplifier. A 3-foot cable is brought into the base of the operating handle and contains the switch control

circuit, megaphone circuit to the amplifier, and amplifier output circuit to the loudspeaker.

The amplifier case consists of two separate metal cabinets that are fastened together by four spring-loaded latches. The upper cabinet contains the audio amplifier and a vibrator power supply. The lower cabinet contains a 6.3-volt 3-cell lead-acid storage battery. When the two cabinets are latched together the circuit between the two units is completed by plug-in connectors on the bottom of the amplifier cabinet and on the top of the battery cabinet cover.

Two connectors and a volume control for the remote microphone are mounted at the rear of the amplifier cabinet. The left-hand connector is for the megaphone cable that connects the megaphone to the amplifier; the right-hand connector is for the remote microphone or the battery-charging cable.

Remote Microphone

The remote microphone is a portable high-impedance unit connected to an 8-foot cable and plug. The unit can be used instead of the microphone mounted on the megaphone to increase the output of the megaphone by reducing feedback or for convenience. The talk switch is connected in parallel with the trigger-operated switch in the operating handle of the megaphone unit.

A schematic diagram of the public address set is illustrated in figure 6-9. The input circuit of the remote microphone differs slightly from the input circuit of the megaphone microphone. When the remote microphone plug P2 is connected to the amplifier jack J2 the output of the remote microphone is connected to the dual variable resistor volume control R2 comprising R2A and R2B. When R2 is advanced it shorts out parts of R2A and R2B to reduce the resistance between the microphone and grids of V1A and V1B in the amplifier. This type of input circuit cancels out the effect of distributed capacitance to ground to make the microphone cable audio circuit a balanced line. When the remote microphone is plugged into the amplifier, the two microphone input circuits are in parallel. The volume control R1 of the megaphone-microphone should be turned to the LOW position. When the remote microphone is not plugged into the amplifier, its input circuit has no effect on the input to the megaphone-microphone.

Amplifier

The amplifier is designed for a frequency response of from 400 to 5,500 cycles. It consists primarily of three push-pull stages, relay K1, and vibrator power supply Z1 (fig 6-9). The push-pull stages minimize noise originating in the vibrator supply. A battery-charging transformer T2 and bridge rectifier CR1 are also mounted on the amplifier chassis.

The output of the microphone MK1 and the volume control R1 are connected directly to the grids of V1A and V1B across R3 and R4. The output of V1A and V1B is resistance-capacitance coupled to the grids of V2A and V2B. The output of V2A is coupled to the grid of output tube V3 through C3 and R11 and the output of V2B is coupled to the grid of V4 through C4 and R12. A bias voltage of -22.5 volts (across R13) is applied to the control grids of V3 and V4. The B+ voltage for the plate circuit is applied to the center tap of the output transformer T1. Transformer T1 matches the impedance of the loudspeaker voice coil to the V3 and V4 plate load impedance.

The 6-volt lead-acid storage battery is the primary source of power. The battery provides the A voltage supply for the tube filaments and also operates the vibrator power supply Z1. The synchronous vibrator is a hermetically sealed unit and provides a rectified high-voltage output for the B+ voltage supply and an intermediate-voltage a-c output which is applied to the bias voltage rectifier-and-filter circuit (CR2, R14, and C5).

When the trigger-type pushbutton on the megaphone operating handle (or the talk switch on the remote microphone) is depressed, switch S1 (or S2) is closed to energize the operating coil of relay K1 and complete the A supply circuit from the battery to the filaments of V1 and V2. The resistance of the relay coil serves as a dropping resistor to reduce the voltage applied to the filaments of V1 and V2 to approximately 1.5 volts. The coil also functions as a filter inductor to reduce harsh noise from the vibrator power supply, Z1. Relay K1 also applies the +6 volt output of the battery through contacts 3-5 to the 6-volt filaments of V3 and V4.

Relay K1 applies the 6-volt output of the battery through contacts 4-6, L1, and L2 to the center tap of transformer, T3, of the power supply Z1. The vibrator power supply produces

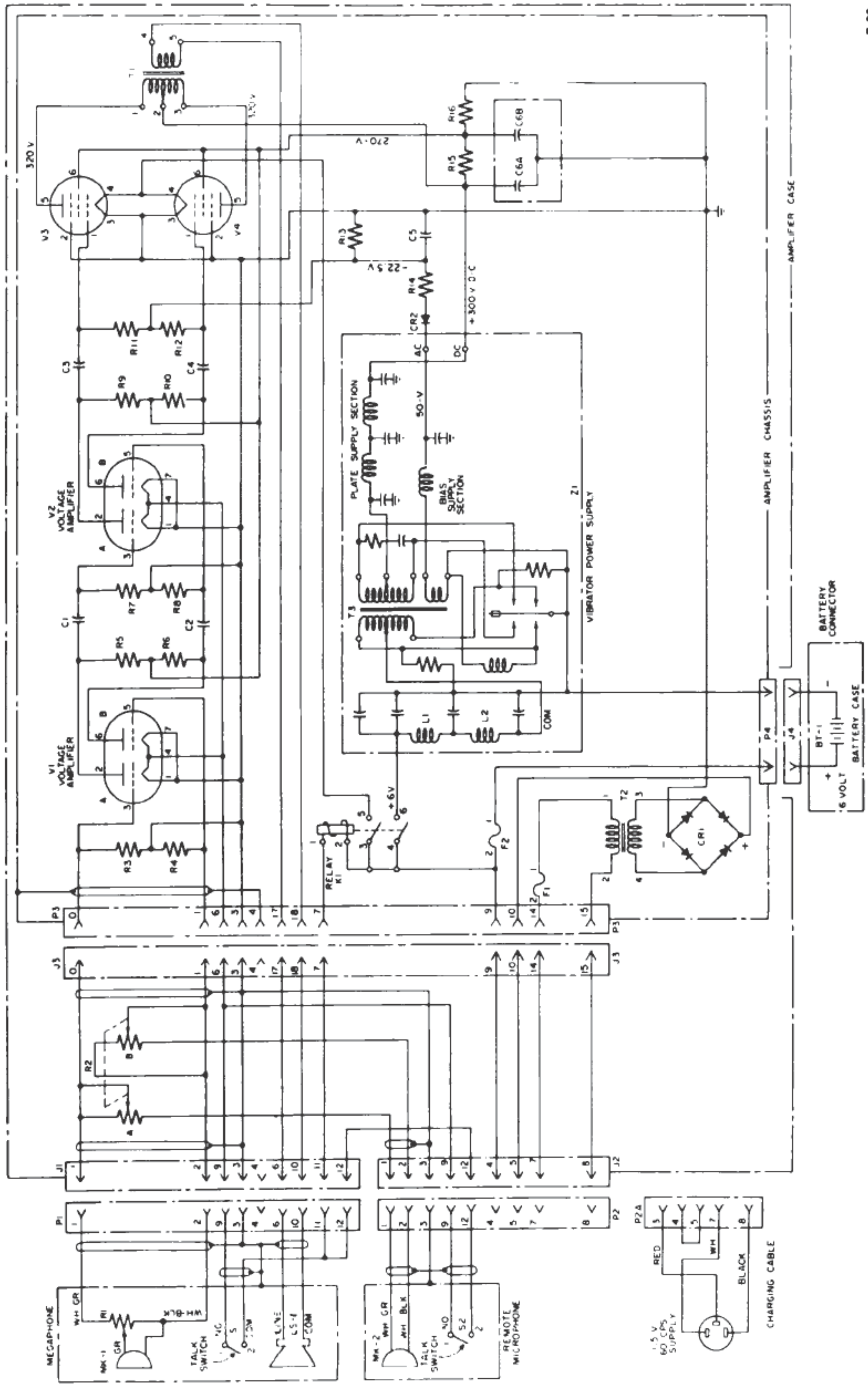

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Figure 6-9.—Schematic diagram of public address set.

a 300-volt d-c output that is fed to the center tap of the amplifier output transformer T1. The 300-volt d-c output of ZI is applied to the plates of V3 and V4 and is also applied to the filter circuit consisting of C6A, R15, and C6B, and bleeder resistor R16. The 270-volt d-c output of this filter is the B+ voltage supply for the plates of V1 and V2 and for the screens of V3 and V4.

Transformer T3 of the power supply Z1 is provided with an additional secondary winding that produces a 50-volt a-c output. This voltage is applied to rectifier CR2 and the filter-and-voltage divider circuit consisting of R13, R14, and C5 and is fed to the control grids of V3 and V4. A negative C voltage (derived from the bias supply section of T3 via CR2) of -22.5 volts is tapped off at the junction of R13 and R14 and applied as bias to the control grids of V3 and V4.

The battery can be charged by means of the battery-charging circuit in the amplifier and the battery-charging cable. The public address set can be operated while the battery is being charged. The battery charging circuit is capable of charging the battery in 15 hours from a discharged condition in which the green and yellow indicator balls are down.

The battery-charging circuit (fig. 6-9) comprises the stepdown transformer T2, the bridge rectifier CR1, and fuses F1 and F2. To charge the battery, inspect the electrolyte level. If necessary, add water to about one-eighth inch below the level line. Connect the plug P2A on the battery-charging cable to the right-hand connector on the amplifier case and plug the other end of the cable into the ship's 115-volt 60-cycle supply. Charge the battery until the yellow indicator balls rise; observe the electrolyte level and add water if necessary. Continue charging until the green indicator balls rise to the electrolyte level. Charge the battery for about one-half hour more. Stop charging if excessive bubbling occurs. Continue the charge if the green balls drop with the addition of water.

OPERATION

The public address set is designed for intermittent operation. A total operating cycle of 2 hours at 50 percent on and 50 percent off is available from the fully charged battery.

The equipment is energized by the trigger switch S1 on the megaphone handle, or by the remote microphone talk switch S2. The switch should be closed only during periods of actual voice transmission. The continuous operation for a period of more than 10 minutes will tend to damage the vibrator power supply by overheating. Follow each operating period, if possible, by an equal deenergized period. The operating time should not exceed the deenergized time in any 1 hour operating cycle. For best results, operate the equipment in exposed areas away from enclosures and obstructions.

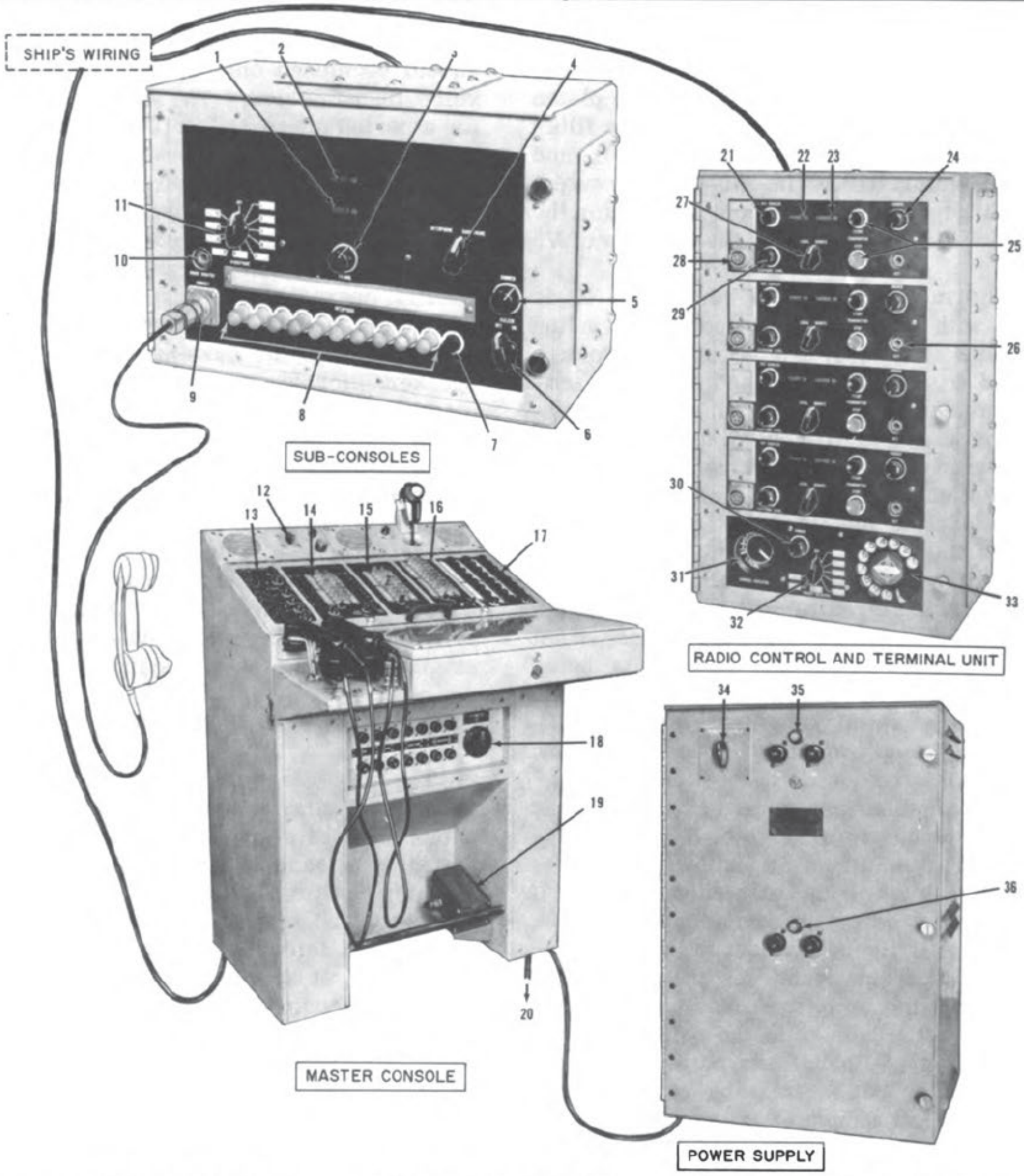
To operate the system, utilizing the loudspeaker microphone, plug the connector on the megaphone cable into the left-hand connector on the amplifier case (fig. 6-8). Turn the microphone volume control R1 completely counterclockwise and depress the trigger switch on the operating handle. Turn the volume control clockwise gradually until acoustic feedback begins. Turn the volume control counterclockwise until feedback stops. Speak a few test syllables into the microphone and listen for singing following the test syllables.

MAINTENANCE

The I. C. Electrician should follow a logical process of elimination in locating a fault in the public address set. First, investigate the points that are the easiest to test. For example, if no vibrator hum is heard in the amplifier when the talk switch S1 is depressed, the trouble may be caused by a defect in the vibrator Z1, relay K1, talk switch S1, from open or shorted wiring, or from a dead battery (fig. 6-9). Check the battery charge indicators, check fuse F2, then the talk switch S1, and so forth. Replace the vibrator Z1 as a last resort, because all of the other parts can be tested by observation, substitution, or continuity checks. For example, if trouble is suspected in the megaphone input circuit, the substitution of the remote microphone is the simplest method of checking the location of this fault.

Do not operate or attempt to test the vibrator power supply outside the equipment unless a 50-watt 3,300-ohm dummy-load resistor is connected between the 300-volt terminal and the ground terminal.

If trouble is localized in the amplifier, make voltage tests with no signal input. Apply the battery voltage to the amplifier and measure the voltage between each pin and the chassis of each



1. RADIOPHONE CARRIER ON INDICATOR
2. RADIOPHONE ON THE AIR INDICATOR
3. HANDSET VOLUME CONTROL 4R1
4. RADIOPHONE-INTERPHONE SELECTOR SWITCH 4S12
5. PANEL LIGHTS DIMMER CONTROL
6. BUZZER OFF-ON SWITCH 4E1
7. INTERPHONE RELEASE BUTTON 4S11
8. 10 INTERPHONE SELECTOR SWITCHES 4S1 THROUGH 4S10
9. HANDSET PLUG
10. RADIOPHONE MONITOR JACK
11. RADIOPHONE SELECTOR SWITCH 4S14
12. LOW-VOLTAGE POWER SWITCH 3S91
13. RADIO RECORDER-RADIO MONITOR CONTROL PANEL
14. RADIOPHONE CONTROL PANEL
15. INTERPHONE CONTROL PANEL
16. INTERCOM CONTROL PANEL
17. SOUND-POWERED TELEPHONE CONTROL PANEL
18. 115V A-C POWER SWITCH 3S92
19. FOOT-OPERATED INTERCOM TALK SWITCH 3S90
20. 115-VOLT, 60-CYCLE POWER
21. SQUELCH BUTTON 5S4
22. RADIOPHONE POWER ON INDICATOR 5I1
23. RADIOPHONE CARRIER ON INDICATOR 5I2
24. PANEL LIGHTS DIMMER CONTROL 5R6
25. TRANSMITTER CONTROL BUTTONS 5S2 & 5S3
26. RADIOPHONE MONITOR JACK 5J2
27. LOCAL-REMOTE SWITCH 5S1
28. HANDSET PLUG 5J1
29. RADIOPHONE HANDSET EARPHONE LEVEL CONTROL 5R1
30. PANEL LIGHTS DIMMER CONTROL 5R6
31. SYNCHRO CHANNEL INDICATOR M1
32. CIRCUIT SELECTOR SWITCH 6S1
33. TELEPHONE DIAL CHANNEL SELECTOR 6S2
34. POWER SUPPLY SELECTOR SWITCH 1S1
35. POWER SUPPLY 1 INDICATOR LAMP 2I1
36. POWER SUPPLY 2 INDICATOR LAMP 2I2

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Figure 6-10.—Communication console equipment.

tube, using a 20,000 ohm-per-volt voltmeter. Replace the tubes if the voltages, with a fully charged battery, are not within ±10 percent of the values listed in the applicable manufacturer's technical manual.

If the fault persists, take resistance measurements between each pin and the chassis for each tube with the amplifier deenergized. The measurements must be made with the common (negative) lead of the ohmmeter placed on the chassis. Compare these readings with normal values listed in the technical manual. If the trouble is not located, proceed with point-to-point resistance and continuity measurements (fig. 6-9).

COMMUNICATION CONSOLE EQUIPMENT

The communication console equipment centralizes the control of voice communication circuits at key tactical stations in the ship. The components consist of a master console, subconsole, radio control and terminal unit, and power supply (fig. 6-10). The system may comprise one or two master consoles, 12 subconsoles, four radio control and terminal units, and one or two power supplies, depending on the requirements of the individual ship, as illustrated by the block diagram in figure 6-11.

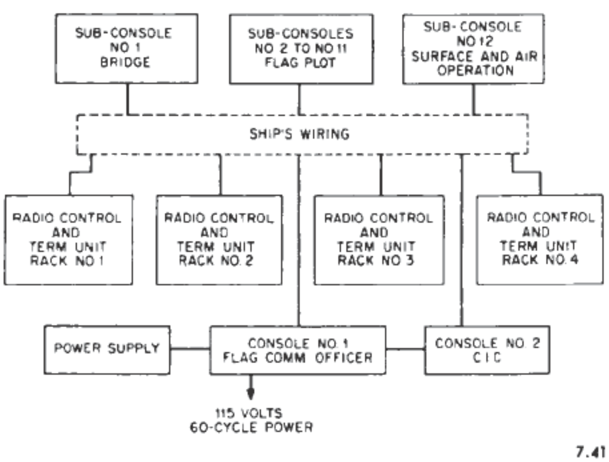

Figure 6-11.—Block diagram of communication console system.

MASTER CONSOLE

The master console (fig. 6-10) centralizes the control of voice communication circuits in one master control station. It provides for the control of from 1 to 16 tactical radiophone circuits for both transmitting and receiving; provides communication with any combination, up to 10 of 20 intercom stations; and provides two-way communication and monitoring on any combination of 14 sound-powered telephone circuits.

The console is usually installed in CIC (Combat Information Center) and is used by the evaluator and CIC officer. When two consoles are installed they are usually located adjacent to each other and used by the flag communication officer and the CIC communication officer. Therefore, either console permits local control of any tactical radiophone circuit and monitoring of any sound-powered telephone circuit connected to the equipment.

The operating controls of these circuits are mounted on individual panels, accordingly to function, to comprise the control panel assembly. These controls (left to right) are (1) radio recorder-radio monitor, (2) radiophone, (3) interphone, (4) intercom, and (5) sound-powered telephone control panels. A microphone is provided for connection to the 20MC circuit.

The 115-volt main power switch 3S92 mounted above the kneehole recess, supplies power to the five amplifiers and to two step-down transformers (not shown). The secondaries of these transformers are connected in series and provide power for the 12-volt a-c LO, NEUTRAL, HI, and INTERMITTENT circuits.

The low-voltage power switch 3S91, mounted above the control panel assembly, supplies 12-volt a-c NEUTRAL, HI, and INTERMITTENT power to the remainder of the system except for the 12-volt d-c power necessary to operate the carbon microphones and relays.

The foot-operated switch 3S90 located in the right side of the kneehole recess, is connected in parallel with (and can be used instead of) the intercom TALK-LISTEN switch.

SUBCONSOLE

The subconsole (fig. 6-10) provides a secondary control point for the radiophone and the interphone circuits. The switching and indicating controls for 10 interphone and 10 radiophone circuits are mounted on the front panel.

The radiophone selector switch provides for selecting any one of 10 radio circuits for both

transmitting and receiving. A connector for a handset and a jack is provided for monitoring the selected radiophone circuit.

The interphone selector switches provide for the selection of 10 interphone circuits for two-way or network communication from the sub-console to the master consoles and to the other subconsoles.

RADIO CONTROL AND TERMINAL UNIT

The radio control and terminal unit (fig. 6-10) comprises four radio terminal units and a channel selector unit enclosed in a metal cabinet. Each terminal unit is used to control one remote radio transmitting or receiving circuit. The radiophone circuit can be controlled from the terminal unit or from the consoles and sub-consoles. A connector for a handset is mounted on each terminal unit for local control or monitoring of the associated radio circuit. Provision is also made at each terminal unit for the connection of a loudspeaker amplifier for local loud-speaker monitoring of the radio circuit.

The channel-selector unit is provided with a selector switch, telephone-type dial, and synchro indicator. The selector switch can select any one of the four transmitters or the four receivers connected to the terminal units in the cabinet. The telephone-type dial, by remote action, selects the desired channel of the transmitter or receiver. The synchro indicator indicates the channel on which the transmitter or receiver is set.

POWER SUPPLY

The power supply (fig. 6-10) is designed to operate from the ship's 115-volt 60-cycle power and consists of two identical power supplies housed in a metal cabinet. Each power supply comprises a step-down transformer, rectifier, and filter circuit (not shown) necessary to provide the 112-volt d-c power to operate the carbon microphones and relays used in the equipment.

The selector switch 2S1, mounted on the cabinet, is used to select the power supply for active service while the other power supply serves as a standby. When the main power switch S392, on the master console is in the ON position, 115-volt 60-cycle power is applied to power supply 1 or power supply 2, depending on the position of the selector switch 2S1. The indicator lamps 2I1 and 2I2 provide a visual indication that power is supplied to the associated power supply 1 or 2.

MASTER CONSOLE OPERATION

Before applying power to the communication console equipment, place the switches of all units in the OFF position. Release the push-button switches on the radiophone, interphone, and intercom control panels at the master console and the interphone pushbutton switch at the subconsole by depressing the red release buttons.

Be certain that the ship's 115-volt 60-cycle power is connected to the master console. Place the main power switch 3S92, and the low-voltage power switch 3S91, in the ON position (fig. 6-10). The main power indicator lamp on the console will light to indicate that the entire system is energized.

If two master consoles are connected in parallel, place the low-voltage power switch and the 115-volt power switch on each unit in the ON position. If one of the paralleled consoles is turned off, for standby operation or for maintenance, be certain to turn off the low-voltage power switch and the 115-volt power switch. The remaining console will supply power to the other components of the system.

Radiophone Circuit

The communication console equipment permits selection and operation of 16 radiophone circuits at the master console and 10 radiophone circuits at the subconsole. Each radio circuit is controlled through a radio-terminal unit. The circuits can be operated from the master console and subconsole or from the radio control and terminal units. However, the application of power and the selection of the frequency channel for each radio circuit is possible only at the related radio terminal unit or at the transmitter.

A simplified schematic diagram of one of the radiophone circuits of the master console is illustrated in figure 6-12. All radiophone circuits are identical, except for the designations of the indicator lamps, resistors, and switches. Certain minor electrical parts, such as crystal rectifiers that are connected across relay coils to reduce noise transients are not shown.

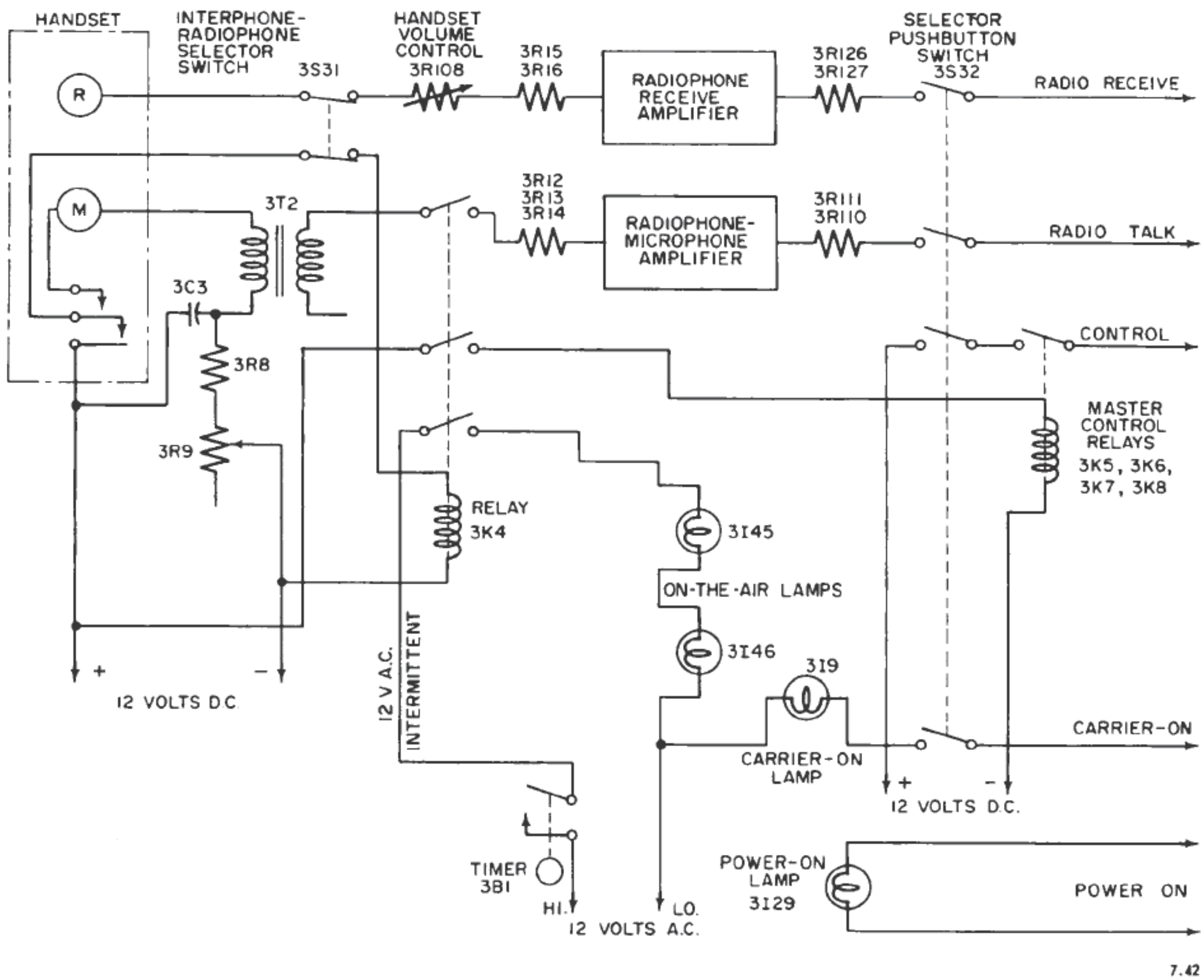

Figure 6-12.—Simplified schematic diagram of console radiophone circuit.

When it is desired to operate a radiophone circuit, observe the power-on numeral indicator lamps (3I29 through 3I44) of the circuit to be operated. When power is applied to the corresponding radio terminal unit and the local-remote switch of this unit (fig. 6-10) is in the REMOTE position, the associated power-on indicator lamp 3I29 (in this case), is lighted (red) to indicate that the transmitter can be operated from the master console.

Place the radiophone-interphone rotary switch 3S31 at the master console in the RADIOPHONE position (fig. 6-12). Depress the pushbutton selector switch 3S32 (in this case), of the desired radiophone circuit at the master console. If the carrier-on indicator lamp 3I9, associated with the channel to be operated is lighted (green), it indicates the transmitter is being operated from another station. If the carrier-on indicator lamp is not lighted, the transmitter can be operated from the master console.

The radiophone-interphone switch 3S31, when in the RADIOPHONE position, connects the handset receiver to the output of the radiophone-receiver amplifier and the handset talk switch to the operating coil of relay 3K4.

The selector pushbutton switch 3S32, when depressed, connects the radio receive line from the associated radio-terminal unit to the input of the radiophone-receive amplifier; the radio talk line to the output of the radiophone-microphone amplifier; the +12-volt d-c line in

the console to a set of normally open contacts of relay 3K8; and the carrier-on line from the associated radio-terminal unit to the carrier-on indicator lamp 3I9.

The radiophone handset talk switch, when depressed, applies 12-volt d-c power to the microphone and energizes relay 3K4. Relay 3K4, connects the secondary of the handset microphone transformer 3T2, to the input of the radiophone-microphone amplifier and completes the circuit of the on-the-air lamps, 3I45 and 3I46, between the LO and INTERMITTENT lines of the 12-volt a-c power circuit, causing the lamps to flash intermittently. The timer, 3B1, is energized from the ship's 115-volt 60-cycle power to provide interrupted connection for the 12-volt a-c intermittent circuit.

Relay 3K4, also energizes the master control relays 3K5, 3K6, 3K7, and 3K8. Each of the four master control relays is provided with four sets of contacts. Each of the 16 sets of contacts completes the control circuit between one of the 16 selector pushbutton switches, 3S32 through 3S47, and the corresponding radio terminal unit. When the radiophone handset talk switch is depressed, the four master control relays operate simultaneously. The +12-volt d-c power, however, is applied only to the contacts of the associated selector pushbutton switch (3S32 in this case) that is depressed. When the control circuit to the radio terminal unit is completed, the associated transmitter is placed in operation and the carrier-on indicator lamp 3I9, in the master console is lighted (green). Release the radiophone handset talk switch to listen. At the conclusion of the message depress the release button to release the selector pushbutton switch 3S32.

The output of the handset microphone is fed through resistors 3R12, 3R13, and 3R14 to the input of the radiophone-microphone amplifier. The resistors reduce the output of the handset microphone to the input operating level of the amplifier. The output of the radiophone-microphone amplifier is fed through the isolating resistors 3R110 and 3R111, the selector pushbutton switch, 3S32, and the radio talk line to the radio terminal unit (not shown).

The output of the radio receiver is delivered from the radio terminal unit, the radio receive line, through the selector pushbutton switch, 3S32, and the isolating resistors, 3R126 and 3R127, to the input of the radiophone-receive amplifier. The output of the radiophone-receive amplifier is reduced through resistors 3R15 and 3R16 and fed through the handset volume control, 3R108, to the handset receiver.

The isolating resistors 3R110, 3R111, 3R126, and 3R127 serve to permit simultaneous operation on several channels without crosstalk. The amplifiers function to compensate for loss in signal level caused by the isolating resistors. The radiophone-receive amplifier input-terminating resistor 3R17 (not shown), reduces the volume level at the handset.

Radio Recorder-Radio Monitor Circuits

The operator at the master console can record and play back parts of the messages received on any one of the 16 radio circuits by using the radio (short-memory) recorder. The controls for the radio recorder are located on the upper section of the radio recorder-radio monitor control panel (fig. 6-10). To monitor a radio circuit with the recorder, place the on-off power switch in the ON position and switch the circuit selector switch to the circuit to be monitored. The circuit selector switch connects any one of the 16 radio monitoring channels to the input of the short-memory recorder. The recorder output is connected to the loudspeaker located directly above the radio recorder-radio monitor control panel on the master console.

The delay selector switch is provided for selecting the time delay for playing back the recorded message and permits the selection of any one of five different recorder outputs, each having a specific time delay. When the delay selector switch is set at position 1, no delay is provided and the message will be heard over the radio recorder loudspeaker as soon as it is received. When the delay selector is set at a higher number, part of the message will be repeated and the remainder of the incoming message will be delayed. If the delay selector is set at a lower number during play back, part of the message will be omitted. The maximum delay is 60 seconds. Adjust the loudspeaker volume control to the desired level by turning the speaker volume control located below the delay selector switch.

The operator at the master console can monitor four radio channels simultaneously on four overhead loudspeakers. The controls for the

radio monitor are located on the lower section of the radio recorder-radio monitor control panel (fig. 6-10). The four selector switches are connected to the monitor circuits of the 16 radio channels and each switch permits the selection of any one channel. Thus, four channels can be monitored at the same time. Each selector switch is connected through a volume control to terminals for the external connection of the monitor loudspeaker amplifiers. The four volume controls permit adjustment of the volume level of the individual loudspeakers.

To monitor a circuit, set the circuit selector switch of the loudspeaker to be used for monitoring to the desired radio circuit and adjust the volume to the desired level by moving the speaker volume control. Monitoring through any of the loudspeakers can be interrupted without disturbing the setting of the selector switch by turning the associated speaker volume control to the extreme counterclockwise position.

Loudspeaker monitoring of the radio circuits at the radio-control and terminal units is also possible if monitor amplifiers and loudspeakers are connected to these units.

Interphone Circuit

The interphone circuits provide an independent telephone system between the master console and the subconsoles. The controls for interphone circuits are located on the interphone control panel at the master console (fig. 6-10). The subconsoles are provided with connections for 10 interphone circuits.

A simplified schematic diagram of one interphone circuit between a master console and a subconsole is illustrated in figure 6-13.

The interphone circuits can be operated from the master console or from the subconsoles. For interphone operation from the master console or subconsole, the interphone-radiophone selector switch (3S31 on console and 4S12 on subconsole) must be placed in the INTERPHONE position. The radiophone-interphone switch, 3S31, transfers the handset to either the

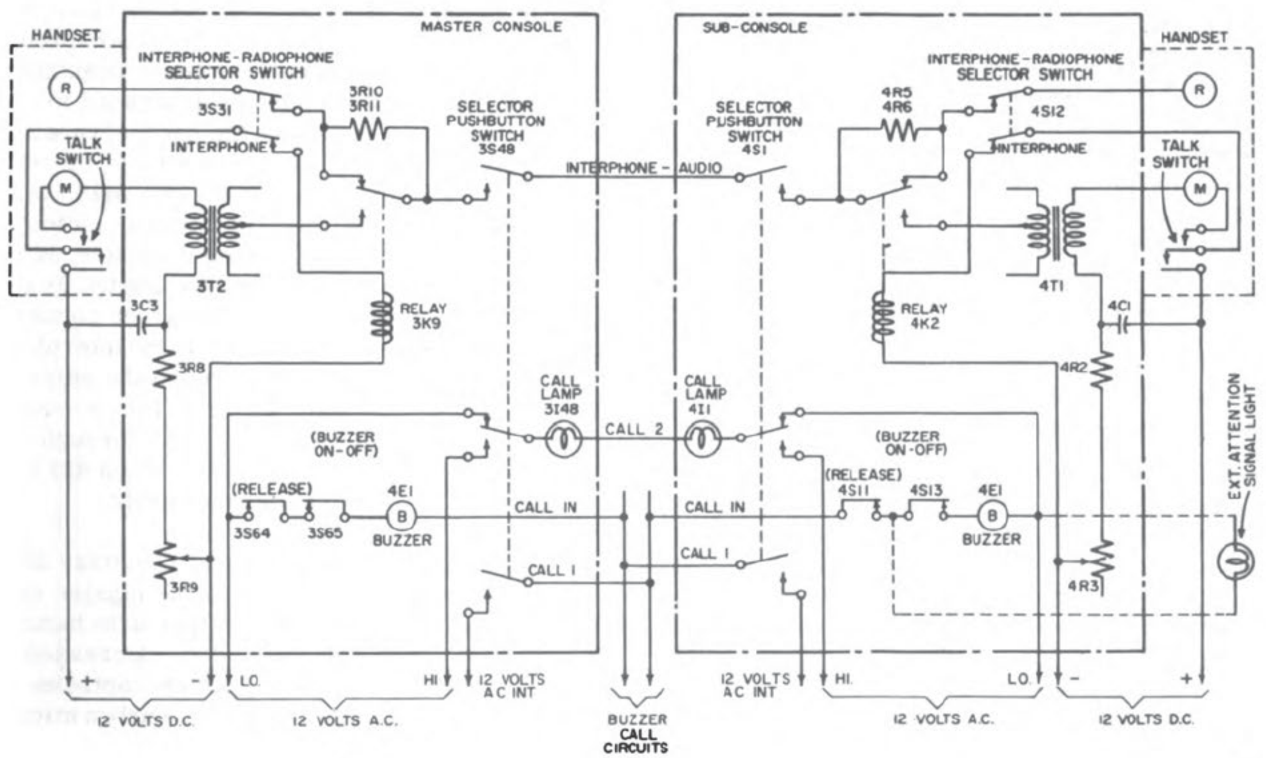

Figure 6-13.—Simplified schematic diagram of interphone circuit between master console and sub-consoles.

interphone or radiophone circuits. A handset is also provided at each subconsole and can be used for either interphone or radiophone communication.

To call another interphone station from the master console, place the radiophone-interphone selector switch 3S31, located on the radiophone control panel (fig. 6-13) in the INTERPHONE position. Depress the selector pushbutton switch (3S48) of the called station to complete the circuit of interphone call line (CALL 2) between the HI and LO lines of the 12-volt a-c power supply. This action causes the call lamp indicator 3I48, associated with selector switch 3S48, on the master console and 4I1 on the subconsole to light (blue). The CALL 2 line is an independent line connecting in series the call lamp indicators at the master console and the subconsole. A separate CALL 2 line connects each two stations in the interphone system.

The selector pushbutton switch 3S48, also completes the call buzzer circuit between the a-c INT and LO lines of the 12-volt a-c power supply from the CALL 1 line at the console to the CALL IN line at the subconsole, causing the buzzer 4E1, at the subconsole to operate. The buzzer CALL IN line at the master console is common to the CALL 1 lines of all interphone stations in the console network. The buzzer CALL IN line at the subconsole is common to the CALL 1 lines of any master console or subconsole with which interphone communication is possible. In other words, a separate CALL 1 bus for each station is connected to its associated switch in every master console or subconsole in the interphone system. The call signal buzzer can be cut in or out of the circuit by the buzzer on-off rotary switch 4S13.

When the selector pushbutton switch (3S48 in this case) at the master console is depressed, the release pushbutton 3S64, is automatically opened. Because the release pushbutton 3S64, is in the circuit of the call signal buzzer, the buzzer is prevented from sounding when the interphone is in use. However, any incoming call will light (green) the associated call lamp indicator. An interphone call from a subconsole to the master console or another subconsole operates in a similar manner.

When the call indicator lamp 4I1 at the subconsole lights, the operator depresses the selector pushbutton switch 4S1, to disconnect the call light circuit and extinguish the indicator call lamps 4I1 on the subconsole and 3I48 on the master console. The selector switch 4S1, when depressed, also automatically opens the release pushbutton 4S11, at the subconsole to open the buzzer call circuit and silence the buzzer 4E1. The operator then places the radiophone-interphone selector switch 4S12 in the INTERPHONE position to complete the interphone audio lines from the master console to the subconcole.

When the call indicator lamp 3I48, at the master console is extinguished, listen for the reply from the called subconsole station. When the reply is received, depress the talk switch on the radiophone handset and speak into the microphone. At the conclusion of the conversation, depress the release button 3S64, at the master console to release the selector pushbutton switch 3S48.

The radiophone-interphone selector switch 3S31, when placed in the INTERPHONE position (fig. 6-13), connects the receiver of the handset on the master console through the normally closed contacts of relay 3K9, to the 16 interphone selector pushbutton switches (3S48 through 3S63). When the interphone selector pushbutton switch (3S48 in this case) is depressed to call the subconsole, it connects the handset receiver to the INTERPHONE AUDIO line from the subconsole. The indicator call lamp 3I48, when extinguished at the master console, indicates the circuit is completed to the subconsole. When the master console handset talk switch is depressed, it energizes relay 3K9 which connects the handset microphone circuit to the interphone audio line. The circuit is through the selector pushbutton switch 4S1, through the normally closed contacts of relay 4K2, and through the radiophone-interphone selector switch 4S12, to the handset receiver at the subconsole.

The series voltage-dropping resistors 3R10 and 3R11, provide sidetone to the master console handset receiver. The output of the handset microphone can be increased or decreased by the variable resistor 3R9, which controls the magnitude of current through the carbon microphone. Normally, resistor 3R9 will not require readjustment if properly set when installed. The interphone audio circuit at the subconsole operates in a similar manner.

Intercom Circuit

The intercom circuits in the master console are interconnected with the units in the ship's intercommunicating system. The controls for the intercom circuits are located on the intercom control panel at the master console (fig. 6-10). The selector switches permit the selection of 20 intercom stations. Up to 10 stations can be selected simultaneously at the full audio power output. If more than 10 stations are called, the audio power output at the called stations will be reduced.

A simplified schematic diagram of the master console intercom circuit is illustrated in figure 6-14. The foot-operated switch 3S90, mounted in the kneehole recess of the master console is connected in parallel with the listen-talk switch 3S88, mounted on the intercom control panel and can be used instead of the panel switch. Depress the foot switch to talk and release it to listen.

The 20 selector pushbutton switches (3S66 through 3S85) are mechanically interlocked with the release pushbutton switch 3S86. The release switch 3S86, when automatically operated by

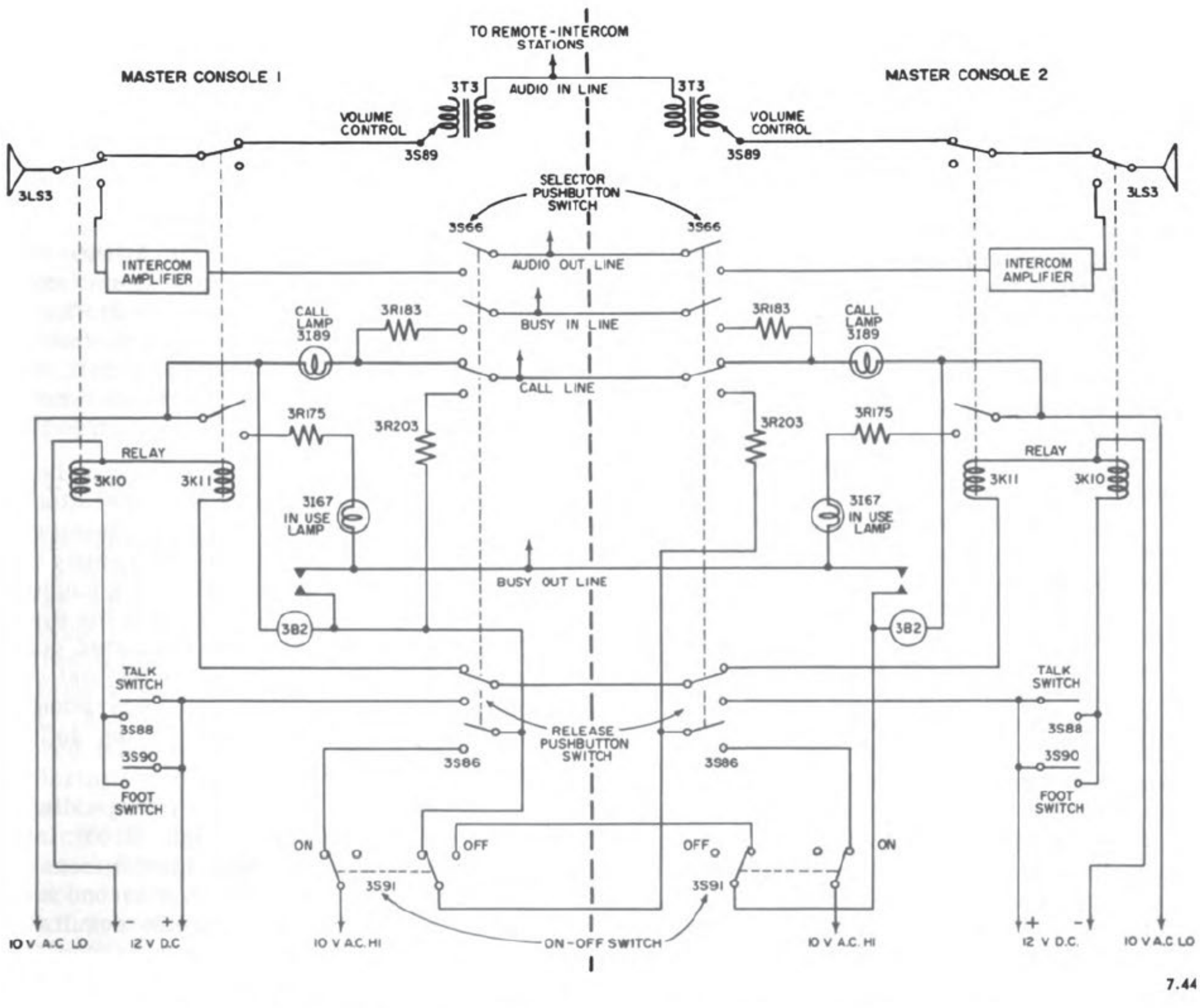

Figure 6-14.—Simplified schematic diagram of console intercom circuit.

depressing any selector pushbutton switch (3S66 in this case) disconnects relay 3K11, in master console 1 from the corresponding release switch 3S86, in master console 2; applies +12-volt d-c power through the release switch 3S86, to relay 3K11, in console 2; applies 10-volt, a-c HI power to the flasher motor 3B2, which applies 10-volt a-c INT power to the BUSY OUT line (any station calling the master console will get a busy signal because the console BUSY OUT line is the console BUSY IN line for other stations in the system); and applies 10-volt a-c HI power through 3R203 to a contact on the selector pushbutton switch 3S66.

To call an intercom station, depress the selector pushbutton switch (3S66 in this case) corresponding to the station to be called. The selector switch 3S66, connects the output of the intercom amplifier to the selected AUDIO OUT line; disconnects the call indicator lamp 3I89, from the CALL line and applies 10-volt a-c power (through dropping resistor 3R203) to the CALL line of the selected station to light the indicator call lamp 3I89, at the station selected; and connects the BUSY IN line of the selected station through 3RI83 to the call indicator lamp 3I89.

If the called station is busy, the call indicator lamp 3I89, at the calling station (master console 1) flashes (amber) intermittently. The light flashes as a result of the 10-volt a-c HI power applied to the console BUSY IN line by the flasher motor 3B2, at the called intercom station (not shown). In this event depress the release pushbutton 3S86, to release the selector pushbutton switch 3S66.

If the called station is not busy, the call indicator lamp 3I89, at the calling station will not light. Depress the listen-talk switch 3S88, on the intercom control panel or the foot switch 3S90, to the TALK position and speak clearly into the intercom loudspeaker 3LS3. When the called station replies by depressing the proper selector pushbutton switch (3S66 in this case) the call indicator lamp 3I89, at the calling station (console 1) will flash intermittently as long as the calling station is connected with the called station. The light flashes as a result of the 10-volt a-c HI power applied to the console BUSY IN line by the flasher motor 3B2, at the called intercom station.

To listen, release the listen-talk switch 3S88, or the foot switch 3S90. Adjust the loudspeaker volume to the desired level by the volume control knob located at the left of the listen-talk switch. At the conclusion of the message, depress the release pushbutton 3S86, to release the selector pushbutton switch 3S66.

The listen-talk switch 3S88, or the foot switch 3S90, when depressed, energizes relay 3K10 which transfers the loudspeaker 3LS3, from the line transformer 3T3, in the AUDIO IN line to the input of the intercom amplifier. The output of the amplifier is applied to the AUDIO OUT line of the selected station.

When a remote intercom station calls the master console, the intercom control panel indicator lamp, 3I89 (console 1), associated with the calling station will be lighted (amber) steadily with 10-volt a-c HI power from the calling station and the message will be heard on the intercom loudspeaker 3LS3. To reply, depress the selector pushbutton switch 3S66, associated with the lighted call lamp 3I89. This action causes the call light to flash intermittently, indicating that the master console and the calling station are connected. The signals on the AUDIO IN line pass through the loudspeaker volume control 3S89, to the intercom loudspeaker 3LS3, on the master console 1. Answer over the intercom speaker by depressing the listen-talk switch 3S88, to the talk position or by operating the foot switch 3S90. Release the switch to listen.

Two adjacent master consoles can be connected in parallel for intercom operation (fig. 6-14). When the two master consoles are paralleled, they are connected in a single interlocking circuit and are selected as a single station at the other intercom units in the system. Parallel operation of the two master console intercom circuits is the same as that of the single master console circuit operation with the exceptions discussed in the following paragraphs.

Incoming calls light the corresponding call indicator lamps (3I89 through 3I108) in both master consoles. If either master console is busy on the intercom circuits, a second incoming call to the master console results in a flashing busy signal being transmitted to the calling station. The busy signal is generated by the flasher motor 3B2, in console 1. The flasher motor 3B2, in console 2 is cut out of the circuit as long as switch 3S91 in console 1 is in the ON position (fig. 6-14).

When a remote station calls the master consoles, the call indicator lamps 3I89, are lighted steadily and incoming speech is heard over both intercom loudspeakers until one master console replies to the call. If master console 1 replies to or initiates a call by depressing selector pushbutton switch (3S66 in this case), the release pushbutton 3S86, at console 1 applies +12-volt d-c power to the relay 3K11, at master console 2. Relay 3K11 in turn opens the AUDIO IN circuit to the intercom loudspeaker 3LS3, in master console 2 to prevent acoustic feedback. Relay 3K11, in master console 2 also connects the IN USE lamp 3I67, through R175 to the 10-volt a-c LO power, causing the IN USE lamp 3I67, in console 2 to flash through the BUSY OUT line. The light will flash as long as the selector pushbutton switch 3S66, is depressed in console 1 to indicate that the intercom circuits on console 2 are not to be used. The call indicator lamp 3I89, on console 2 will be lighted steadily through the corresponding selector pushbutton switches 3S66, in the two paralleled consoles.

If desired, both master consoles can communicate with remote stations if the corresponding selector pushbutton switches on both intercom control panels are depressed. Neither of the IN USE lamps 3I67 will be operated. The incoming voice will be heard in both intercom loudspeakers.

Sound-powered Telephone Circuit

The sound-powered telephone circuits provide a method of communication between the master console and the ship's sound-powered telephone system. The controls for the sound-powered telephone circuits are located on the sound-powered telephone control panel (fig. 6-10). Any combination of 14 separate sound-powered telephone circuits can be selected for monitoring or transmitting without cross-talk and up to seven additional sound-powered telephone circuits can be paralleled.

A simplified schematic diagram of one of the sound-powered telephone circuits of the master console is illustrated in figure 6-15. The selection for monitoring or communication of any combination of 14 sound-powered telephone circuits is made by the talk-off-mon selector switches (3S1 through 3S14). The paralleling of up to 7 additional sound-powered telephone circuits is made by the para-off selector switches (3S16 through 3S22). The transmitting or monitoring of the paralleled circuits is made by the para-line selector switch 3S15. All of the paralleled circuits are common to switch 3S15. Each incoming sound-powered telephone line is connected to one of the 14 talk-off-mon selector switches or to one of the 7 para-off selector switches. The sound-powered telephone handset is located on the master console adjacent to the radiophone-interphone handset.

TO MONITOR a sound-powered telephone circuit or circuits, select the desired station(s) by placing the associated talk-off-mon selector switch(es) in the MON position. When switch (3S1 in this case) is in the MON position, the incoming telephone signal passes through the isolating resistors 3R38 and 3R39, to the input of the monitor amplifier. The isolating resistors permit the simultaneous monitoring of several or all of the circuits without interference between circuits. The incoming speech is amplified and applied to the sound-powered telephone loudspeaker 3LS1. The speaker volume control 3S23, in conjunction with resistors 3R19 through 3R23, provide a method of cutting the speaker in or out of the circuit or adjusting the output to the desired level.

To TALK on a sound-powered telephone circuit or circuits, select the desired station(s) by placing the corresponding talk-off-mon selector switch(es) in the TALK position. When the talk-off-mon selector switch (3S1) is in the TALK position, the incoming telephone signal passes through the isolating resistors 3R24 and 3R25, through a set of normally closed contacts of relay 3K2, and a set of normally closed contacts of relay 3K1 to the input of the handset amplifier (fig. 6-15). The output of the amplifier is fed through a set of normally closed contacts of relay 3K3, the padding resistors 3R1 and 3R2, and the handset volume control 3R18, to the handset receiver.

Depress the handset talk switch and speak into the microphone. Release the handset button to listen. When the handset talk switch is depressed, relays 3K1, 3K2, and 3K3 are energized simultaneously (1) to disconnect the handset receiver from the output of the handset amplifier; (2) to connect the microphone circuit to the input of the handset amplifier; and (3) to transfer the sound-powered telephone line from the input to the output of the handset amplifier.

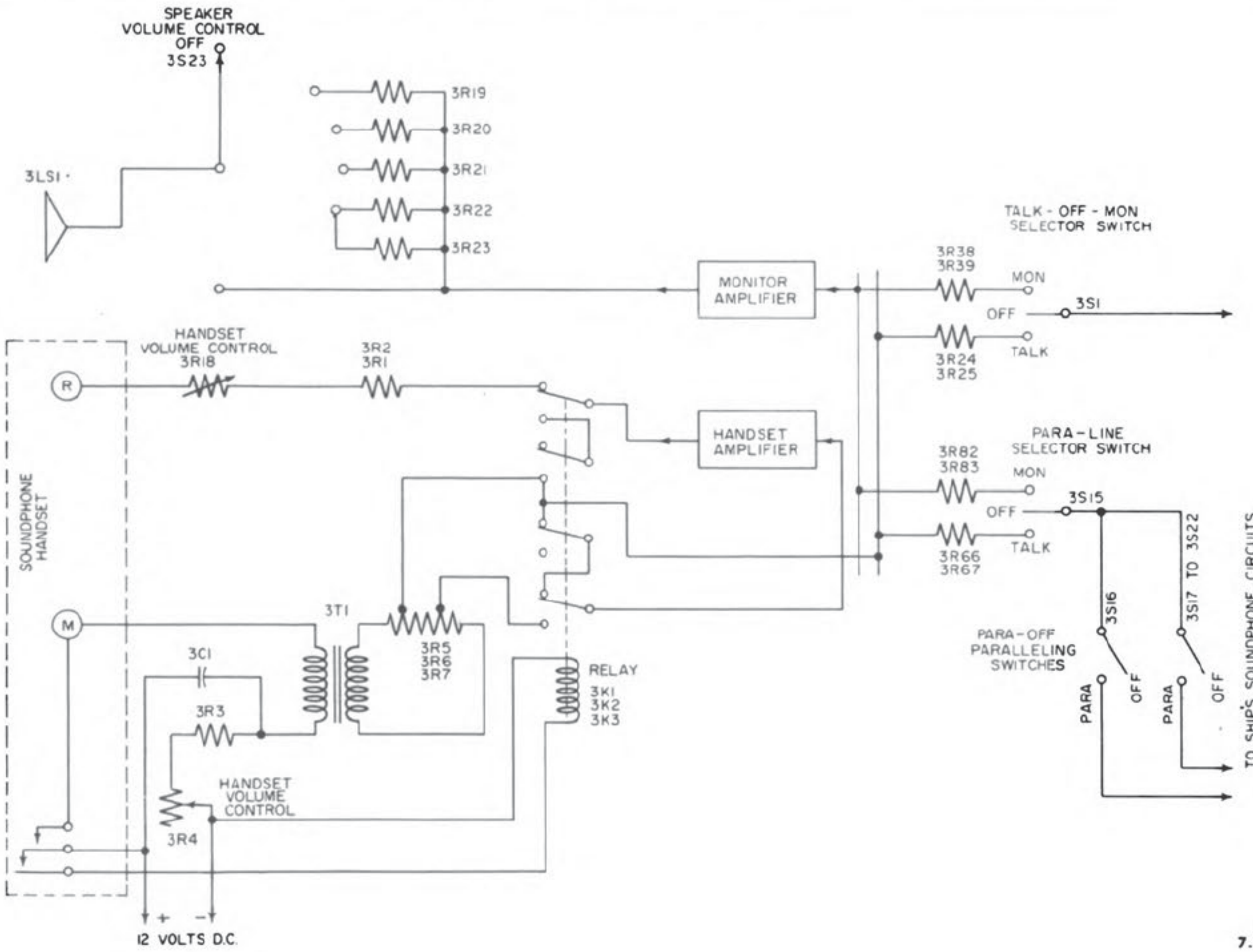

Figure 6-15.—Simplified schematic diagram of console sound-powered telephone circuit.

The handset talk switch also connects the 12-volt d-c line to the microphone circuit. The output of the handset microphone can be increased or decreased by using the volume control 3R4. The isolating resistors 3R24 and 3R25, permit simultaneous communication with several or all of the sound-powered telephone lines connected to the talk-off-mon selector switches 3S1 through 3S14, at the master console without crosstalk interference.

When the master console operator talks into the sound-powered telephone handset, he can be heard on all the sound-powered telephone circuits connected to the talk-off-mon selector switches that are in the TALK position. He can also be heard on all the paralleled circuits connected to the para-off switches that are in the PARA position if the para-line selector switch is in the TALK position.

To monitor or talk on two or more PARALLELED circuits, place the para-off switches associated with the stations to be paralleled in the PARA position. When any combination of these switches (3S16 through 3S22) are in the PARA position, the associated sound-powered telephone lines are paralleled. The paralleled lines are not isolated, thus the talkers on these circuits can hear each other. The para-line selector switch 3S15, acts as a master switch for the para-off switches.

When the para-line selector switch 3S15, is in the MON position, the paralleled signals pass through the isolating resistors 3R82 and 3R83, and continue to the input of the monitor amplifier

(fig. 6-15). The incoming speech is amplified and applied to the sound-powered telephone loudspeaker 3LS1, through the speaker volume control 3S23.

When the para-line selector switch 3S15, is in the TALK position, the paralleled signals pass through the isolating resistors 3R66 and 3R67, through a set of normally closed contacts of relay 3K2 and a set of normally closed contacts of relay 3KI to the input of the handset amplifier. The output of the amplifier is fed through a set of normally closed contacts of relay 3K3, the padding resistors 3R1 and 3R2, and the handset volume control 3R18, to the handset receiver. The operation of the handset talk switch, when depressed, is the same as that previously described.

The AMPLIFIERS employed in the various circuits of the master console comprise the (1) sound-powered telephone monitor, (2) sound-powered telephone handset, (3) radiophone-receive, (4) radiophone-microphone, and (5) intercom amplifiers. Only the sound-powered telephone handset amplifier is described because the first four amplifiers are identical and the intercom amplifier is described in chapter 5 of this training course.

A schematic diagram of the sound-powered telephone handset amplifier is illustrated in figure 6-16. It consists of voltage stages V1 and V2, output stage V3, and power rectifier V4. The signals from the microphone of the sound-powered telephone handset are fed to the input transformer T1. The secondary of T1 is shunted by the potentiometer R1, and the voltage at the arm of R1 is fed to the grid of V1. The output of V1 is resistance-capacitance coupled to the grid of V2 through R5 and C1. The output of V2 is resistance-capacitance coupled to the grid of V3 through R9 and C2. The output of V3 is directly coupled to the output transformer T2. A portion of the output of V3 is also coupled to the cathode of V2 through the degenerative feedback circuit C7 and R12. The function of this

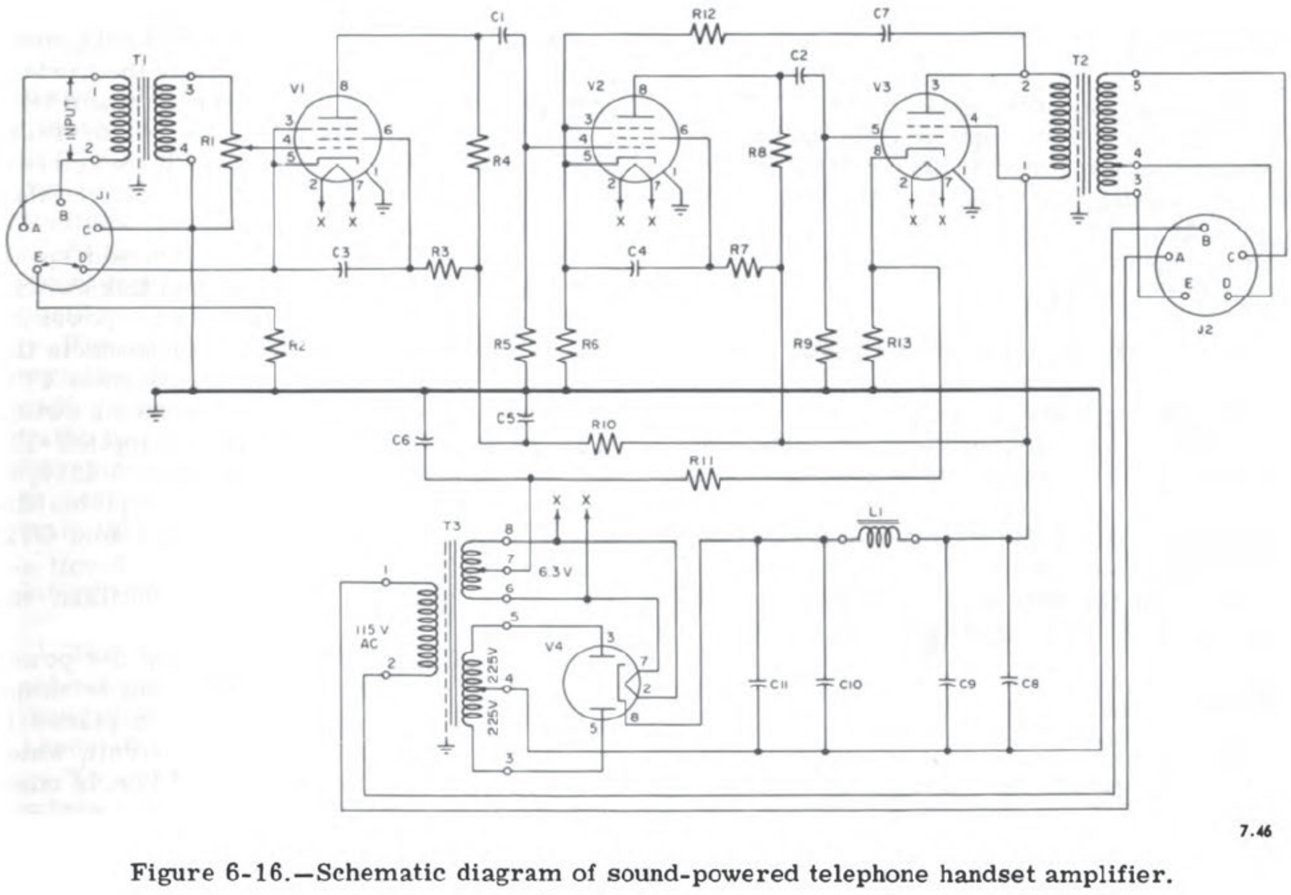

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Figure 6-16.—Schematic diagram of sound-powered telephone handset amplifier.

feedback circuit is to suppress high frequencies, noise, and to improve the quality of the output signal. The power supply operates from the ship's 115-volt 60-cycle power and supplies the necessary filament plate and screen voltages. It consists of the power transformer T3, and the full-wave rectifier V4. The rectified voltage is filtered by a capacitor-input filter system comprising C11, C10, L1, C9, and C8. The heater winding on T3 is raised above ground potential by the cathode biasing resistor R13, to reduce the voltage difference between cathode and filament and thereby reducing hum. The filter resistor R11, capacitor C6, and the center tap returns to the filament winding also to reduce hum. When the sound-powered telephone monitor amplifier is plugged into the console, the filter circuit 3C2 and 3L1 (not shown), is connected into the cathode circuit of V1 to provide more natural sounding speech when the sound-powered telephone signal is amplified and reproduced by a loudspeaker. In the other three amplifiers the cathode circuit is completed by a jumper between terminals D and E of J1.

Circuit 20 MC

To make announcements on the 20 MC circuit, remove the microphone from the bracket, depress the talk switch at the top of the (microphone) housing, and talk into the microphone (fig. 6-10). At the end of the announcements, release the talk switch and replace the microphone in the holder.

SUBCONSOLE OPERATION

As previously stated, the subconsole provides a secondary control point for the radiophone and the interphone circuits. It is designed for the selection of any one of 10 radio circuits for transmitting and monitoring and for the selection of 10 interphone circuits for two-way communication from the subconsole to the master consoles and the other subconsoles (fig. 6-10).

Radiophone Circuit

The controls for radiophone operation at the subconsole (fig. 6-10) consist of a radiophone-interphone selector switch 4S12, and a radiophone circuit selector switch 4S14. A handset is provided for either radiophone or interphone communication, and a radio monitor jack 4J2, is provided for earphone connection.

A simplified schematic diagram of one subconsole radiophone circuit is illustrated in figure 6-17. A handset connector 4J1 (not shown), is provided for either radiophone or interphone communication. The radiophone-interphone selector switch 4S12, connects the handset to either the radiophone circuits or the interphone circuits. The radiophone selector switch 4S14, permits the selection of the desired radio circuit. The monitor jack 4J2, is connected to the radio circuit irrespective of the position of switch 4S12. When switch 4S12 is in the RADIOPHONE position, the handset can be used also to monitor the selected radio circuit.

To operate the radiophone circuit from the subconsole, place the radiophone-interphone switch 4S12, in the RADIOPHONE position and set the radiophone selector switch 4S14, to the desired circuit. If the carrier-on lamps 4I13 and 4I14, are not lighted, the channel is ready for operation. Conversely, if the carrier-on lamps are lighted (green) the selected circuit is in operation from another station.

The radiophone-interphone switch 4S12, when in the radiophone position, connects the handset receiver through the handset volume control 4R1, and the radiophone circuit selector switch 4S14, to the radio receive line of the selected circuit (fig. 6-17). It also connects the coil of relay 4K1 to the handset talk switch.

Depress the handset talk switch and speak into the microphone. The handset talk switch, when depressed, applies 12-volt d-c power to the coil of relay 4K1. Relay 4K1 connects the secondary of the microphone transformer 4T1, through the radiophone circuit selector switch 4S14, to the selected radio talk line; applies +12-volt d-c power through selector switch 4S14, to the selected control line; and completes the circuit of the on-the-air lamps 4I11 amd 4I12, between the 12-volt a-c LO and the 12-volt a-c INT lines, causing the lamps to flash intermittently.

When relay 4K1 applies +12-volt d-c power through the control line to the radio terminal unit, the associated transmitter is placed in operation. The carrier-on lamp circuit, which is connected to the 12-volt a-c LO line, is completed through switch 4S14 to the selected carrier-on line, causing lamps 4I13 and 4I14 to light (green) steadily. If the carrier-on

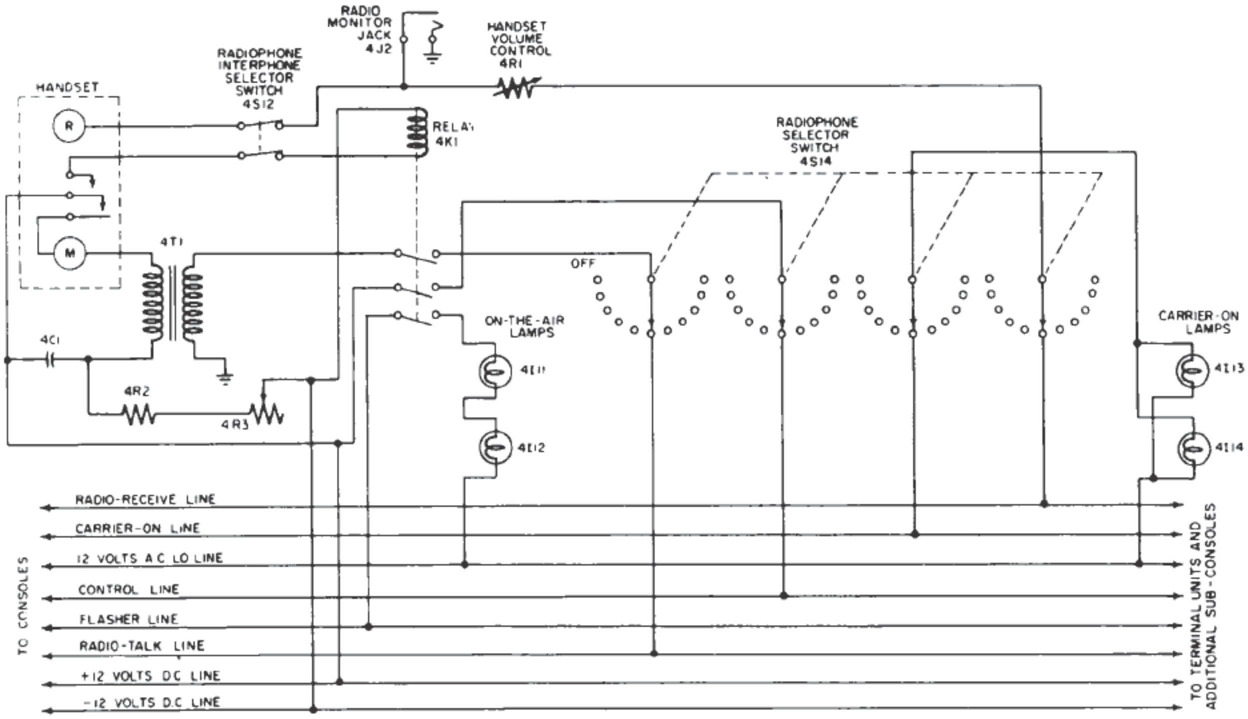

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Figure 6-17.—Simplified schematic diagram of sub-console radiophone circuit.

lamps, 4I13 and 4I14, are not lighted after the handset talk switch is depressed, the transmitter is OFF at the terminal unit, or the local-remote switch at the terminal unit is in the LOCAL position.

At the conclusion of the communication, place the radiophone selector switch 4S14, in the OFF position.

The radio channels can be monitored to determine if any activity exists by operating the radiophone selector switch 4S14, and listening to the handset receiver or to earphones plugged into the radio monitor jack 4J2. If the handset is used, the radiophone-interphone switch must be in the radiophone position.

Interphone Circuit

The controls for interphone operation at the subconsole (fig. 6-10) consists of 10 selector pushbutton switches (4S1 through 4S10) and the associated release pushbutton 4S11.

To operate an interphone circuit from the subconsole (fig. 6-13), place the interphone-radiophone switch 4S12, in the interphone position. Interphone operation at the subconsole is the same as interphone operation at the master console with the following exceptions: the indicator call lamps 4I1 through 4I10, appear as lighted (blue) spots at the center of the designation strip directly above the associated selector switches (4S1 through 4S10); if an external attention signal lamp is installed at the subconsole, it will operate on the buzzer circuit, flashing on an incoming call; the attention signal lamp operates irrespective of the position of the buzzer ON-OFF switch.

RADIO CONTROL AND TERMINAL UNIT OPERATION

A radio control and terminal unit consists of four terminal units and a channel selector unit (fig. 6-10). Each radio circuit associated with the communication console equipment is connected to a terminal unit.

The local remote switch on each terminal unit permits control of the associated transmitter and receiver from the master console or subconsoles (remote) or from the terminal unit itself (local). The channel selector unit consists of a circuit selector switch 6S1, a telephone-type dial 6S2, and a synchro indicator M1. The circuit selector switch 6S1 selects any one of the

four transmitters or four receivers connected to the terminal units in the cabinet. The telephone-type dial 6S2, by remote action, selects the desired channel of the transmitter or receiver. The synchro channel indicator M1 indicates the channel on which the transmitter or receiver is set. The indicator is operated by voltages from synchro transmitters in the tuning mechanisms of the transmitters and receivers.

A simplified schematic diagram of the radiophone circuit of the terminal unit is illustrated in figure 6-18. When the local-remote switch 5S1 is in the REMOTE position (as shown) the radiophone circuit can be operated remotely at the master console and the subconsoles. The receiver circuit can be monitored at the terminal unit when the local-remote switch is in either the REMOTE or LOCAL position. When the switch 5S1 is in the LOCAL position, the radiophone circuit can be operated only from the terminal unit. A handset connector 5J1 is provided on the front panel of each terminal unit.

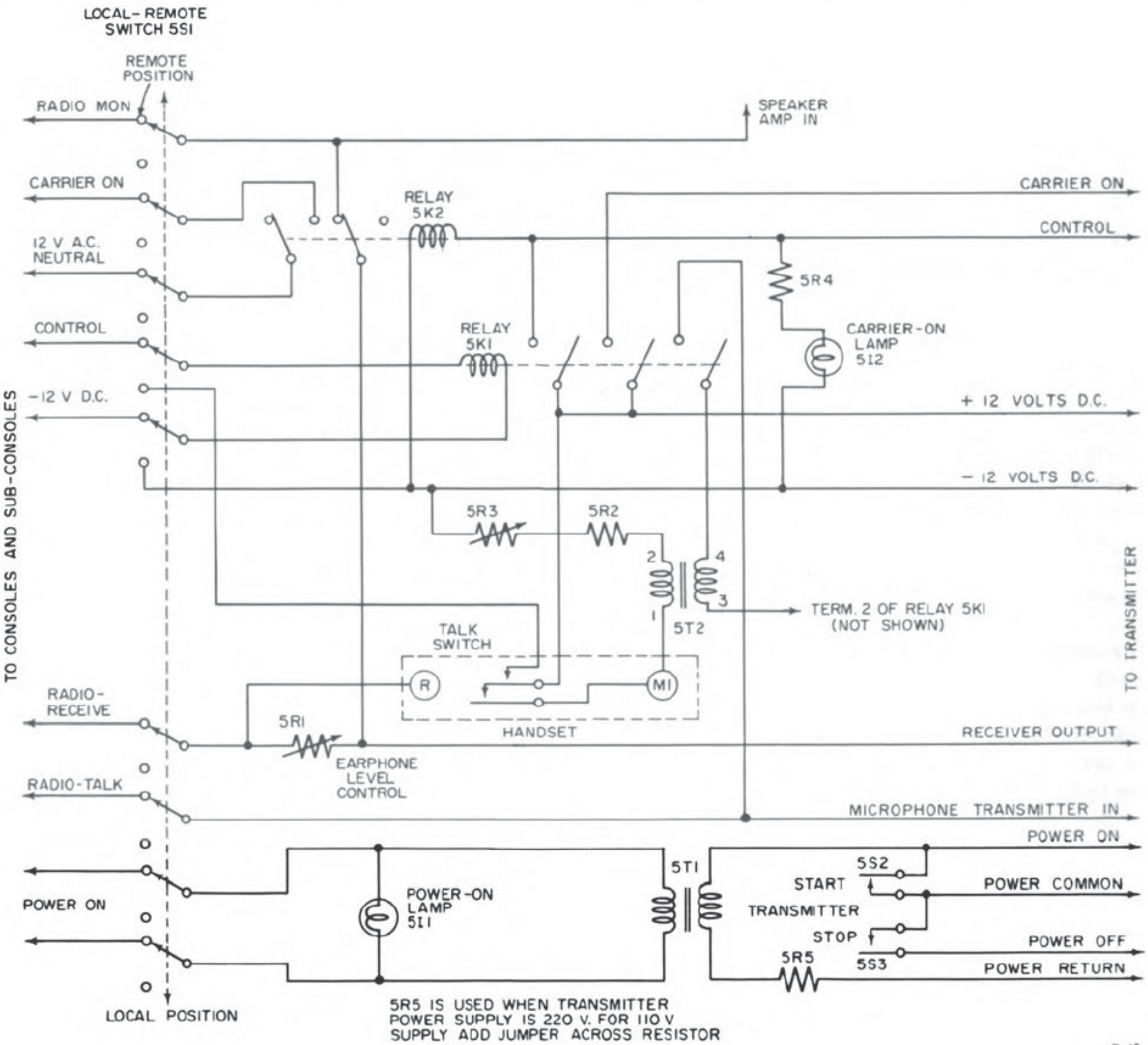

Figure 6-18.—Simplified schematic diagram of terminal unit radiophone circuit.

The earphone volume can be adjusted to the proper level by means of the earphone level control 5R1, located on the front panel of each unit. The control also determines the level of the signals to the console and subconsoles. Each terminal unit is provided with two indicator lamps. The power-on indicator lamp 5I1 lights (red) when power is applied to the transmitter; and the carrier-on lamp 5I2 lights (green) when the transmitter is on the air. A key jack 5J2, and a cut squelch switch 5S4 (not shown), are connected to the radio transmitter and receiver respectively.

Local Operation

To operate the radiophone circuit at the terminal unit, place the local-remote switch 5S1, in the LOCAL position. Energize the transmitter by depressing the transmitter start button 5S2, on the terminal unit of the desired radiophone circuit. The POWER-ON indicator lamp 5I1, will light (red). Connect the handset to the connector 5J1, of the terminal unit (fig. 6-10). Depress the handset talk switch to talk and release it to listen.

The local-remote switch 5S1, when in the LOCAL position, applies -12-volt d-c power from the transmitter to one side of the coil of relay 5K1 (fig. 6-18). The handset talk switch, when depressed, applies +12-volt d-c power from the transmitter, through the local-remote switch 5S1, to the other side of the coil of relay 5K1. Relay 5K1 completes the circuit from the transmitter +12-volt d-c line to the transmitter CONTROL and CARRIER-ON circuits causing the carrier-on lamp 5I2, to light (green) in the terminal unit; completes the circuit from the secondary of the microphone transformer 5T2 to the transmitter; and completes the transmitter +12-volt d-c circuit to the coil of relay 5K2. Relay 5K2 operates but has no effect because all the circuits to the master console and subconsoles are inoperative with switch 5S1 in the LOCAL position. Depress the transmitter stop button 5S3 to deenergize the radio circuit.

Remote Operation

To operate the radiophone circuit at the master console or subconsoles, place the local-remote switch 5S1 in the remote position. Energize the transmitter by depressing the transmitter start button 5S2 on the terminal unit of the desired radiophone circuit. The power-on lamp 5I1 will be illuminated (red).

Set the circuit selector switch 6S1 on the channel selector unit (fig. 6-10) to the position corresponding to the transmitter of the selected radiophone circuit. Select the desired frequency channel by means of the telephone-type dial 6S2. The synchro channel indicator M1 will repeat the number of the selected channel when the necessary selection has taken place at the transmitter.

The local-remote switch 5S1, when in the REMOTE position (fig. 6-18), connects the radio-talk circuit from the master console and subconsoles to the transmitter microphone circuit; applies the receiver output, through the earphone level control 5R1, to the local handset receiver and to the radio-receive circuits at the master console and subconsoles. The receiver output is also applied through normally closed contacts of relay 5K2 to the local speaker amplifier and through switch 5S1 to the radio monitor circuits at the master console. The 12-volt a-c neutral line is connected to a set of normally open contacts of relay 5K2 and the secondary of transformer 5T1 is connected to the associated power-on indicator lamp 3I29 in the master console (fig. 6-12).

A handset talk switch at the master console or subconsoles, when depressed, applies +12 volt d-c power (from the console) through the control circuit and switch 5S1 to relay 5K1 (fig. 5-18). Relay 5K1 completes the circuit from the transmitter +12-volt d-c line to the transmitter control and carrier-on circuits causing the carrier-on lamp 5I2 to light (green) in the terminal unit; completes the circuit from the secondary of the microphone transformer 5T2 to the transmitter; and completes the transmitter +12-volt d-c circuit to relay 5K2.

Relay 5K2 opens the circuits to the local speaker amplifier input and to the radio monitor speakers and recorder at the master console; and closes the circuit between the console 12-volt a-c neutral line and the carrier-on line to the master console and subconsoles causing the selected carrier-on indicator lamp 3I9 (fig. 6-12), to light (green). Depress the transmitter stop button 5S3 to deenergize the radio circuit.

MAINTENANCE

The communication console equipment consists of independent sets of circuits for the various types of communication. Hence, localizing trouble is fairly simple. For example, if trouble is experienced in interphone operation, refer to the schematic diagram in the applicable manufacturer's technical manual and check the interphone circuits to determine the possible faults. In addition, trouble may be further localized by determining if a fault exists in a component that is common to all interphone circuits or to only one circuit. Thoroughly analyze and trace the trouble to the particular faulty unit before disassembling any part of the equipment.

QUIZ

1. What is the purpose of the sound-powered telephone amplifier?
2. How many (a) amplifiers, (b) headsets, and (c) loudspeakers comprise a sound-powered telephone amplifier circuit?
3. How is the output level of the sound-powered telephone amplifier (fig. 6-3) to both the local headsets and loudspeakers controlled?
4. When does the system function as a two-way communication circuit between the local sound-powered telephone stations and the remote station at the sound-powered telephone level (fig. 6-3)?
5. When the ON-OFF power switch S2 is in the ON position (fig. 6-3) how is the telephone line connected to the input transformer T1 to apply a-c power to the sound-powered amplifier?
6. What action occurs when relay K2 operates with respect to the amplifier input and the telephone line (fig. 6-3) when the ON-OFF power switch is in the ON position and the talk switch is operated at one of the local handsets?
7. Name three troubleshooting procedures used to localize trouble in an audio amplifier.
8. When signal tracing a signal through the amplifier (a) to what terminals is the 1,000 cps at 12 milliwatts applied, (b) in what position in the ON-OFF power switch placed, and (c) in what position is the volume control placed (fig. 6-3)?
9. Within what percentage are the voltage readings, attained when signal tracing, considered normal?
10. Where are the voltage readings measured (in question 9) for each tube in the amplifier when signal tracing?
11. Name three uses of the public address set.
12. When the remote microphone is used with the portable address set (fig. 6-9), how is its talk switch S2 connected to the megaphone microphone talk switch S1?
13. When the remote microphone is used with the public address set (fig. 6-9), how is the effect of distributed capacitance to ground cancelled in the input circuit to the amplifier to make the microphone-cable audio circuit a balanced line?
14. Can the public address set be operated while the battery is being charged?
15. What is the purpose of the communication console equipment?
16. What is the function of the subconsole (fig. 6-10)?
17. What is the function of each terminal unit of the radio control and terminal unit (fig. 6-10)?
18. What is the function of the channel selector unit of the radio control and terminal unit (fig. 6-10)?
19. What is the purpose of the power supply?
20. When power is applied to a radio terminal unit and the LOCAL-REMOTE switch of this unit is in the REMOTE position, what is the condition of the associated power-on indicator lamp 3I29 (in this case), at the master console (fig. 6-12)?
21. When the power-on indicator lamp 3I29 is lighted (red) at the master console, the radiophone-interphone switch is in the radiophone position, and the pushbutton selector switch 3S32 (in this case), of the desired radio circuit is depressed, what does the associated carrier-on indicator lamp 3I9 indicate when (a) lighted (green) and (b) not lighted (fig. 6-12)?

22. How is the secondary of the handset microphone transformer 3T2 connected to the input of the radiophone-microphone amplifier and the circuit completed between the LO and INTERMITTENT lines of the 12-volt d-c power circuit of the on-the-air lamp 3I45 and 3I46 (fig. 6-12)?
23. When the radiophone TALK switch is depressed to energize relay 3K4, how is the control circuit to the radio terminal unit completed to place the associated transmitter in operation and to light (green) the carrier-on indicator lamp 3I9 at the master console (fig. 6-12)?
24. How is a radio circuit monitored with the radio recorder (fig. 6-10)?
25. What is the purpose of the delay selector switch located on the radio recorder panel (fig. 6-10)?
26. How many radio channels can be monitored at the same time (fig. 6-10)?
27. What is the purpose of the interphone circuits (fig. 6-13)?
28. When the call indicator lamp 4I1 at the sub-console is lighted, what action occurs when the operator depresses the selector pushbutton switch 4S1 (fig. 6-13)?
29. When calling an intercom station from the master console, what is indicated (a) when the associated call lamp 3I89 (in this case), flashes intermittently, and (b) when the associated call lamp 3I89 is not lighted (fig. 6-14)?
30. What is the condition of the call lamp 3I89 at the calling station (console 1) when the called intercom station replies to the call by depressing the proper station selector switch 3S66 (fig. 6-14)?
31. When a remote intercom station calls the master console, what is the condition of the associated indicator lamp 3I89 at the master console (fig. 6-14)?
32. When two master consoles are operated in parallel (fig. 6-14) and master console 1 replies to or initiates a call by depressing the selector switch 3S66 (in this case), what two circuits are affected by the operation of relay 3K11 at console 2 which is energized by the release pushbutton 3S86 at console 1?
33. What is the purpose of the sound-powered telephone circuits located on the sound-powered telephone control panel at the master console (fig. 6-10)?
34. Trace the path of the incoming telephone signal when the talk-off-mon switch 3S1 is in the MON position (fig. 6-13).
35. Trace the path of the incoming telephone signal when the talk-off-mon switch 3S1 is in the TALK position (fig. 6-13).
36. When the operator at the master console talks into the sound-powered telephone handset, over which sound-powered telephone circuits can he be heard (fig. 6-14)?
37. Trace the path of the incoming paralleled telephone signals when the para-line selector switch 3S15 is in the MON position (fig. 6-14).
38. Trace the path of the incoming paralleled telephone signals when the para-line selector switch 3S15 is in the TALK position (fig. 6-14).
39. Name the five amplifiers employed in the various circuits of the master console.
40. When radiophone-interphone switch 4S12 at the subconsole is in the radiophone position (fig. 6-16) and the radiophone selector switch 4S14 is set to the desired circuit, what is indicated when the (a) carrier-on lamps 4I13 and 4I14 are not lighted and (b) when they are lighted (green)?
41. What two actions occur when the radiophone-interphone switch 4S12 is placed in the RADIOPHONE position (fig. 6-13)?
42. Name the units that comprise a radio control and terminal unit (fig. 6-10).
43. What is the purpose of the LOCAL-REMOTE switch on each terminal unit (fig. 6-10)?
44. Name the three components that comprise the channel selector unit (fig. 6-10).
45. At what stations can the radiophone circuit be operated when the LOCAL-REMOTE switch is in the (a) REMOTE position and (b) in the LOCAL position (fig. 6-18)?
46. What is indicated when (a) the power-on indicator lamp 5I1 lights (red) and (b) the carrier-on lamp 5I2 lights (green) at the radio terminal unit (fig. 6-18)?
47. When operating a radiophone circuit at the radio control and terminal unit (LOCAL-REMOTE switch 5S1 in LOCAL position), what action results when the handset talk switch is depressed to complete the transmitter +12-volt d-c circuit to the coil of relay 5K2 (fig. 6-18)?

CHAPTER 7

SOUND RECORDING AND REPRODUCING SYSTEMS

Sound recording and reproducing systems are used on board ships and at shore stations to monitor radio and sound-powered telephone circuits for short-memory and permanent-record applications and to record signals for future analysis for instrumentation applications. They are used also to train, entertain, and provide religious services for personnel and for office functions, such as dictation, conference, and telephone recording.

SOUND RECORDING AND REPRODUCING TECHNIQUES

The basic techniques of recording and reproducing sound are (1) mechanical, (2) photographic, and (3) magnetic. The recording medium may consist of a disk, film, tape, or wire, which is usually determined by the recording technique.

MECHANICAL TECHNIQUE

In the mechanical recording technique, the material is mechanically cut (engraved) or deformed (embossed) as it is driven past a stylus, or cutting needle, to form a spiral groove in the recording material and thus preserve the pattern of the sound. The sound pattern can be engraved on disks and embossed on disks or films. Engraving disks are 6 1/2, 8, 10, 12, and 16 inches in diameter, and embossing disks are 7 1/2 and 16 inches in diameter. Embossing films are 60-foot continuous loops that are 35 millimeters wide.

Disk Recording

The components necessary to mechanically record sound are a (1) microphone, (2) audio amplifier, (3) recording head, (4) stylus, and (5) recording medium. The microphone converts the sound waves produced by the voice into corresponding electrical signals that are applied to the amplifier. The output of the amplifier is fed to the recording head, which converts the electrical signals into mechanical energy causing a lateral movement of the stylus. The stylus either engraves or embosses the recording medium as it moves from side to side.

In disk recording a vinalyte disk is rotated at a constant speed, and an engraving or embossing stylus forms a spiral groove in the disk. The RECORDING HEAD, which contains the stylus is driven radially across the disk by a positive drive similar to the lead screw in a lathe (fig. 7-1). The lead screw is geared to the disk drive so that as the disk rotates, the stylus advances radially at a constant speed. In most cases the recording spiral groove begins at the circumference of the disk and ends near the center.

The electric signal received by the recording head causes the stylus to swing from side to side. The lateral motion cuts or deforms the sound pattern on the walls of the groove. Thus, the stylus produces a continuous spiral groove that has small lateral variations that correspond to the audio signals.

The frequency of the sound being recorded determines the frequency of the lateral swings of the stylus, and the volume of the sound determines the amplitude of the swings. The louder the sound picked up by the microphone at a given time, the farther outward will extend the loops of the groove from the middle line of the sound pattern. The higher the pitch of the sound picked up by the microphone, the closer together will be the loops of the groove.

The components necessary to play back a disk recording are a (1) playback head, (2) stylus, (3) audio amplifier, and (4) loudspeaker. When a disk recording is played back, the disk is rotated at the same speed as that at which the recording is made. The playing stylus, or needle, rests in the groove and follows the pattern of the sound groove. The playback head into which the stylus is mounted converts the mechanical movements into corresponding electrical signals, which are applied to the audio amplifier. The output of the

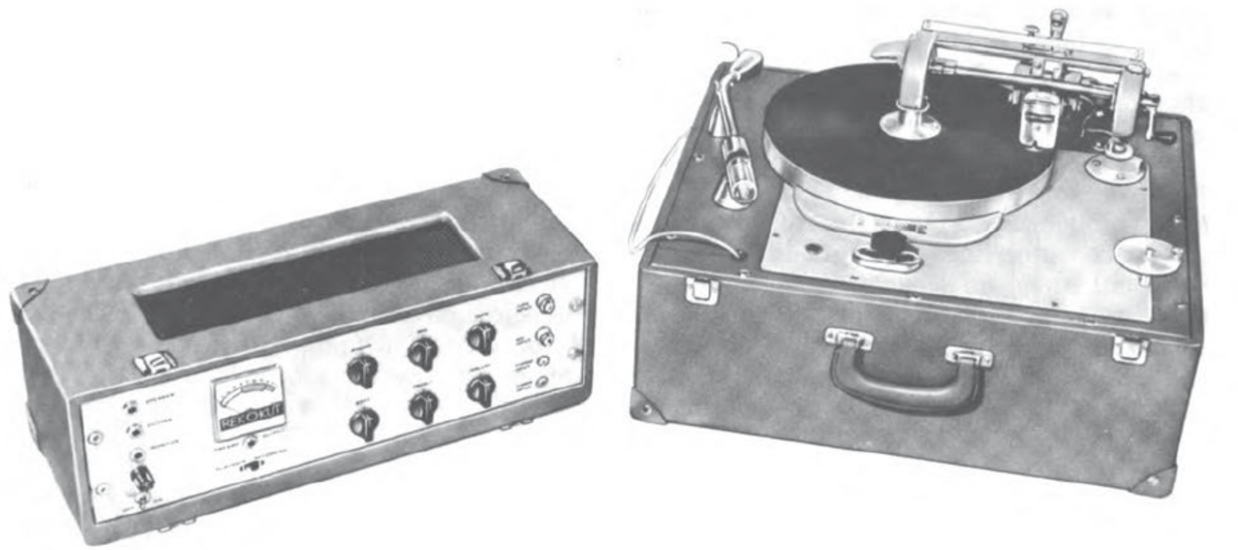

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Figure 7-1.—Disk recording.

audio amplifier is fed to a loudspeaker, which converts the electrical signals into corresponding audio signals.

Film Recording

Mechanical film recording utilizes a 60-foot endless loop of specially treated 35-mm cellulose acetate film. The recording stylus embosses a groove along the film in the same manner as the sound grooves are embossed on the vinalyte disk. An automatic tracking device shifts the recording head sideways across the film at the end of each complete loop of film so that each loop has many independent sound grooves. A tracking counter near the recording head shows which of the available 120 tracks on the film is being used.

When a film recording is played back, the tracking counter is set for the track that contains the desired recording. A log sheet with each length of film lists a record of the contents of each track. The film moves under the playback head, and the playing stylus is moved from side to side by the sound groove in which it rests. The lateral movement of the stylus induces a signal voltage in coils of the playback head, which is fed to the audio amplifier. The output of the amplifier is reproduced as sound waves by the loudspeaker. As in disk recording, sound recorded on film forms a permanent record and cannot be erased.

PHOTOGRAPHIC TECHNIQUE

In the photographic recording technique, the sound is recorded by exposing a moving photosensitive film to a beam of light, which is modulated by the sound pattern being recorded. When the film is developed, it can be reproduced by passing the sound track, which contains the light and dark areas, through a beam of light focused on a photoelectric cell. The output of the cell is fed to an audio amplifier, and then to a loudspeaker, which reproduces the electrical signals into sound waves. The methods of recording sound photographically are (1) variable area and (2) variable density recording.

Variable Area Recording

In variable area recording, the sound pattern is recorded by a small mirror mounted on a sensitive galvanometer. The modulated current produced by the sound vibrations on the microphone is amplified and fed to a sensitive galvanometer consisting of a fine loop of wire. A small

mirror is attached to this loop and the loop is suspended in a magnetic field (fig. 7-2). A beam of light from a high intensity lamp passes through a condenser lens and is focused on the galvanometer mirror from which it is reflected through another condenser lens to a slip or aperture. The resulting slit of light passes through a projector lens onto the film. When current flows through the galvanometer, the wire loop is set in vibration, carrying the mirror with it to trace a line of light not to exceed the width of slit across the sound track of the film. This

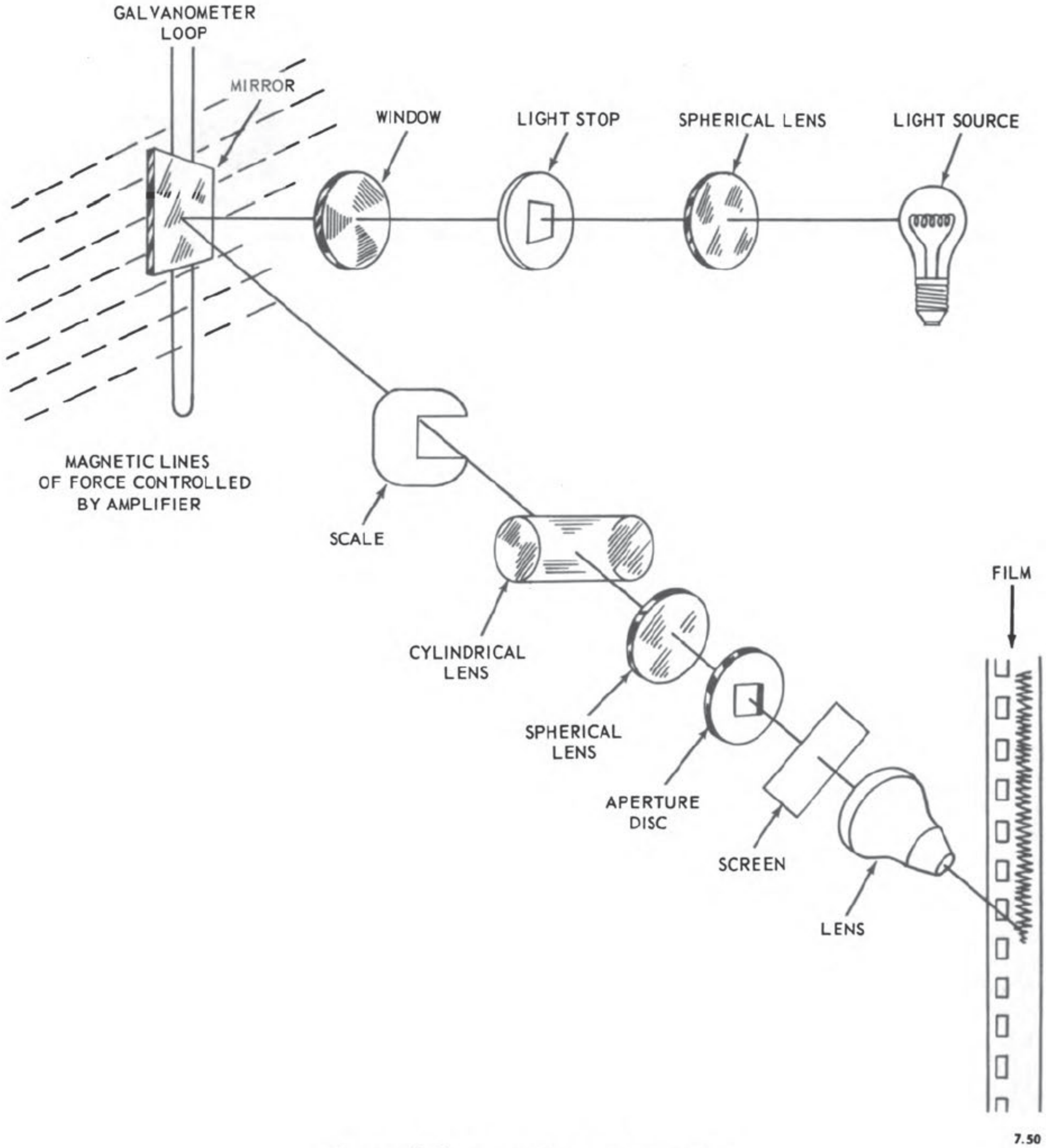

Figure 7-2.—Variable area recording.

type of sound track has a constant density and a varying width along one edge of the film.

Variable Density Recording

In variable density recording, the sound pattern is recorded by varying the densities of the image, which is produced by light passing through a special type of light valve, as shown in figure 7-3, A. The light valve consists of a duraluminum ribbon loop, suspended between the two pole pieces of a powerful electromagnet. The two halves of the ribbon loop are connected to a recording amplifier. The loop opens and closes in response to the input signals to allow varying amounts of light to expose the film as shown in figure 7-3, B and C. This type of sound track has a varying density and a constant width along one edge of the film.

MAGNETIC TECHNIQUE

In the magnetic recording technique, a permanent magnetic material is magnetized in accordance with the pattern of the sound, as the recording medium is driven past a recording head. Similar to mechanical recording, the sound waves are picked up by a microphone, converted to corresponding electrical signals, and amplified. Unliked mechanical recording, the amplified electrical signals are applied to the recording head, which orients the magnetic particles in the tape or wire.

The recording head consists of coils wound on an iron core similar to an electromagnet. During one-half cycle, the signal current flows through the coils in one direction. The iron core becomes magnetized, and establishes a north and a south pole at the ends of the U-shaped electromagnet. A magnetic field exists in the air gap between the poles. When the direction of the current through the coils is reversed, the direction of the lines of force across the air gap is reversed. If a magnetic wire is placed across the gap of the magnet, most of the lines of force would be confined within the wire, and it would become magnetized.

Wire Recording

In magnetic wire recording (fig. 7-4) the output signal from the audio amplifier causes an alternating current to flow through the coils of an electromagnet in the recording head. The current sets up an a-c field of signal frequency across the gaps between the pole pieces (fig. 7-4, A). A stainless steel magnetic wire or nonmagnetic wire plated with magnetic material 4 mils in diameter is drawn axially through the gap at constant speed. The signal constitutes a varying mmf, which orients the molecules in the wire according to the signal pattern. The degree of orientation is proportional to the magnitude of the signal current. Thus, more energy is stored in the magnetic field of the wire with a strong signal than with a weak signal. After recording, a succession of magnetic field patterns differing from each other in length, intensity, and direction (polarity) exists throughout the length of the wire.

When a magnetic recording is played back, the wire or tape is run through a playback head in the same direction and at the same speed that it was during recording (fig. 7-4, B). A series of magnetic fields exists along the length of the recorded wire. Each field has a north and a south pole region. The lines of force extend externally from a north pole to a corresponding south pole for that region. The intensity of these magnetic fields is in proportion to the number of lines representing them.

When one of the magnetic fields lies immediately across the gap between the pole pieces of the playback head (fig. 7-4, B), most of the magnetic lines of force are directed through the wire, and only a part extends out into the space surrounding the wire. As the wire moves across the gap, the varying lines of force induce an emf of signal frequency in the coil. Thus, as the recording wire is drawn across the slot of the playback head, a succession of emf's is induced in the coil. These emf's differ from one another in direction, duration, and intensity, and represent the electrical equivalent of the signal on the wire. The signals are amplified by the audio amplifier and converted into sound waves by the loudspeaker.

Tape Recording

In magnetic tape recording, a flat paper or plastic tape is used as the recording medium (fig. 7-5). The magnetic fields that comprise the sound pattern are established on the tape, which either contains or is coated with very fine steel particles (fig. 7-5, A). The recording head

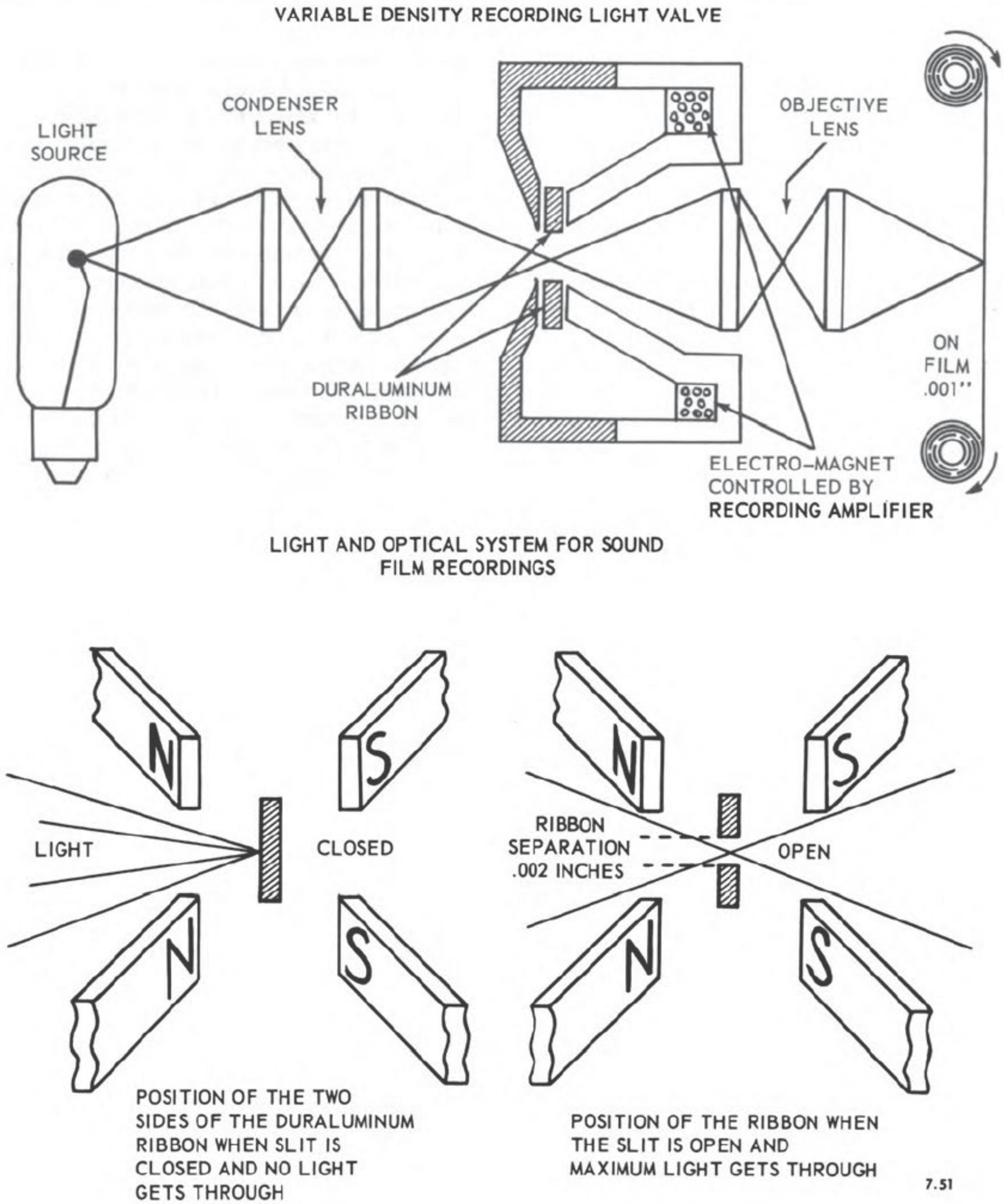

Figure 7-3.—Variable density recording.

and its air gap (fig. 7-5, B) comprise a series magnetic circuit. The principle involved is the same as that for wire recording, but tape recording has the advantage of being easier to handle and less expensive.

A-C Biasing

In most all magnetic recording, an a-c bias is used on which the audio signal is superimposed and applied to the recording head.

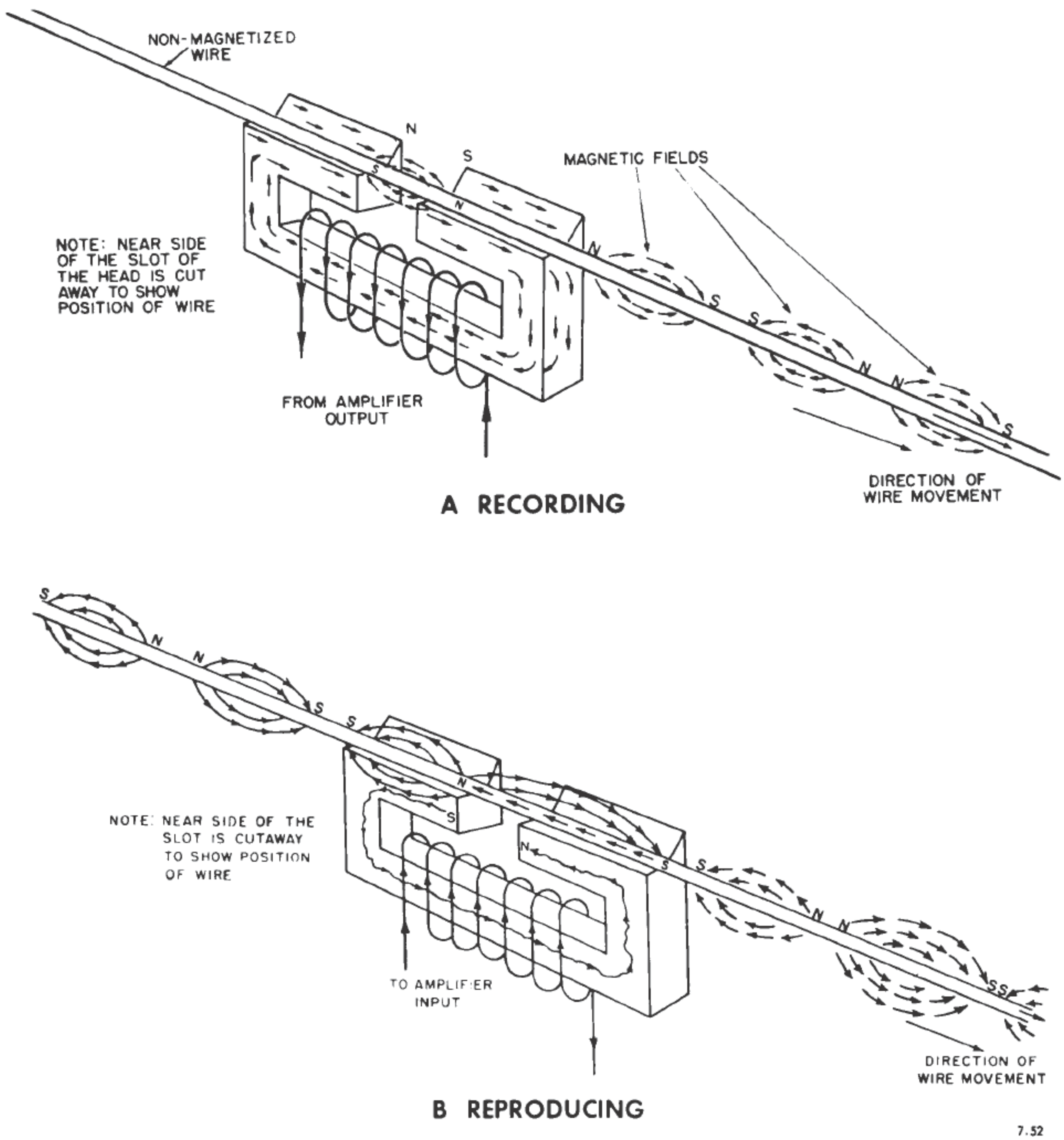

Figure 7-4.—Wire recording.

This bias is a relatively high-frequency, a-c signal, that is above the audio range, and therefore cannot be heard during playback. A-c biasing is used to obtain a substantially linear relationship between the flux density in the recording medium and the magnetizing force. Thus, the induced signal voltages are related linearly to the recording fields.

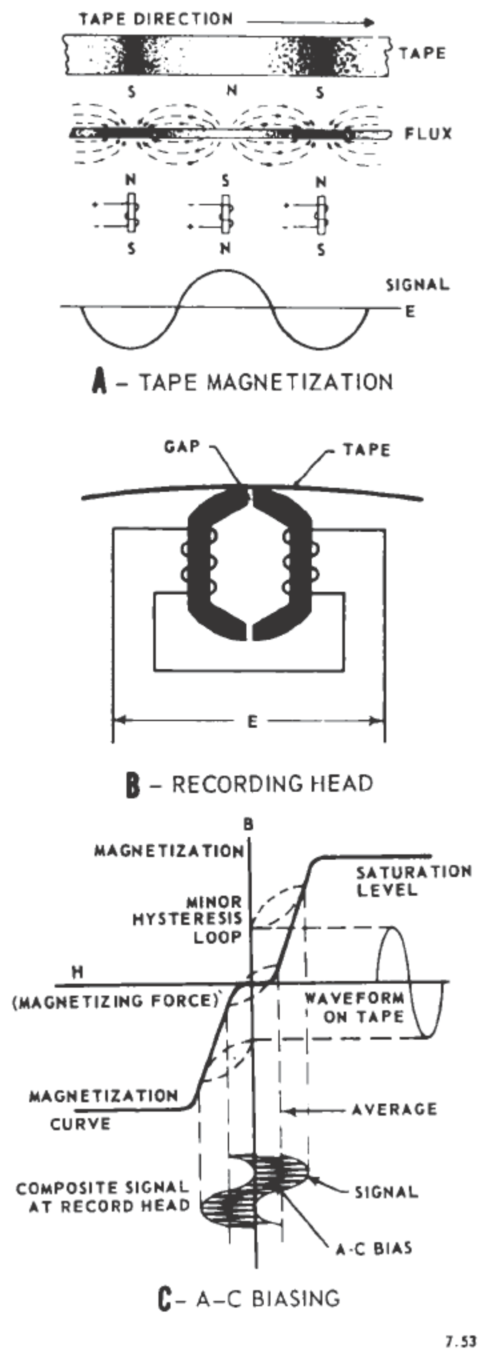

Figure 7-5.—Tape recording.

The magnetization curve (heavy line) of the iron oxide used as the recording medium is similar to that shown in figure 7-5, C. At points near the origin the curve is nonlinear, and without some corrective factor the signal recorded on the tape would not be directly proportional to the signal applied to the recording head. This condition would cause distortion when the tape was played back.

The distortion is greatly reduced by mixing a high-frequency, constant-amplitude signal with the audio signal. The a-c bias is placed in series with the audio signal. This connection causes the average bias to be shifted in a positive direction on the positive alternations of the audio signal and in a negative direction on the negative alternations of audio signal. If the audio signal being recorded is of sine waveform, the flux pattern will be of sine waveform. The waveform is developed from the vertical to horizontal projections obtained from the magnetization (transfer) curve shown in figure 7-5, C.

While the tape is in the recording gap the a-c bias causes the magnetization of the iron oxide to follow the dashed line loops (minor hysteresis loops). As the tape leaves the gap the influence of the mmf is reduced to zero and the degree of magnetization existing at that time depends on the remnant magnetism or that remaining when the magnetizing force is removed.

After the recording process, the flux pattern on the tape is proportional in magnitude and direction to the signal being recorded. If the tape is then moved past a reproduce head that is like the record head, the flux on the tape will induce a voltage in the coil of the reproduce head. This voltage comprises the audio signal.

Notice that the a-c bias keeps the remnant flux sufficiently removed from the origin (zero magnetization with zero magnetizing force) to prevent distortion of the audio signal. The flux pattern established by the a-c bias (100,000 cps) is of sufficiently high frequency not to be heard.

Erasing

The recorded sound track on a magnetic recording medium can be erased (by a special erase head) and the medium used again for further recording. The erase head is located so that the wire or tape must pass through it before reaching the recording head. A high-frequency, a-c signal is fed to the erase head and thus cancels the magnetic fields from a previous recording by completely disorienting the magnetic particles in the wire or tape.

SOUND RECORDER-REPRODUCER SET

The sound recorder-reproducer set (fig. 7-6) is a dual track magnetic tape recorder and reproducer. The equipment consists of a (1) recorder-reproducer assembly, (2) amplifier assembly, and (3) remote control unit (not shown). The recorder-reproducer and amplifier assemblies are located in the upper and lower compartments, respectively, within a cabinet. The assemblies are equipped with rails to facilitate removal from the cabinet for servicing. External wiring to the equipment is connected to a terminal board located on a tray between the assembly compartments in the cabinet. The remote control unit is provided to start and stop the recording function at a location removed from the recorder-reproducer.

A block diagram of the sound recorder-reproducer system is illustrated in figure 7-7. The recorder-reproducer assembly consists of a 2-speed, dual-track magnetic tape transporting mechanism. The amplifer assembly consists

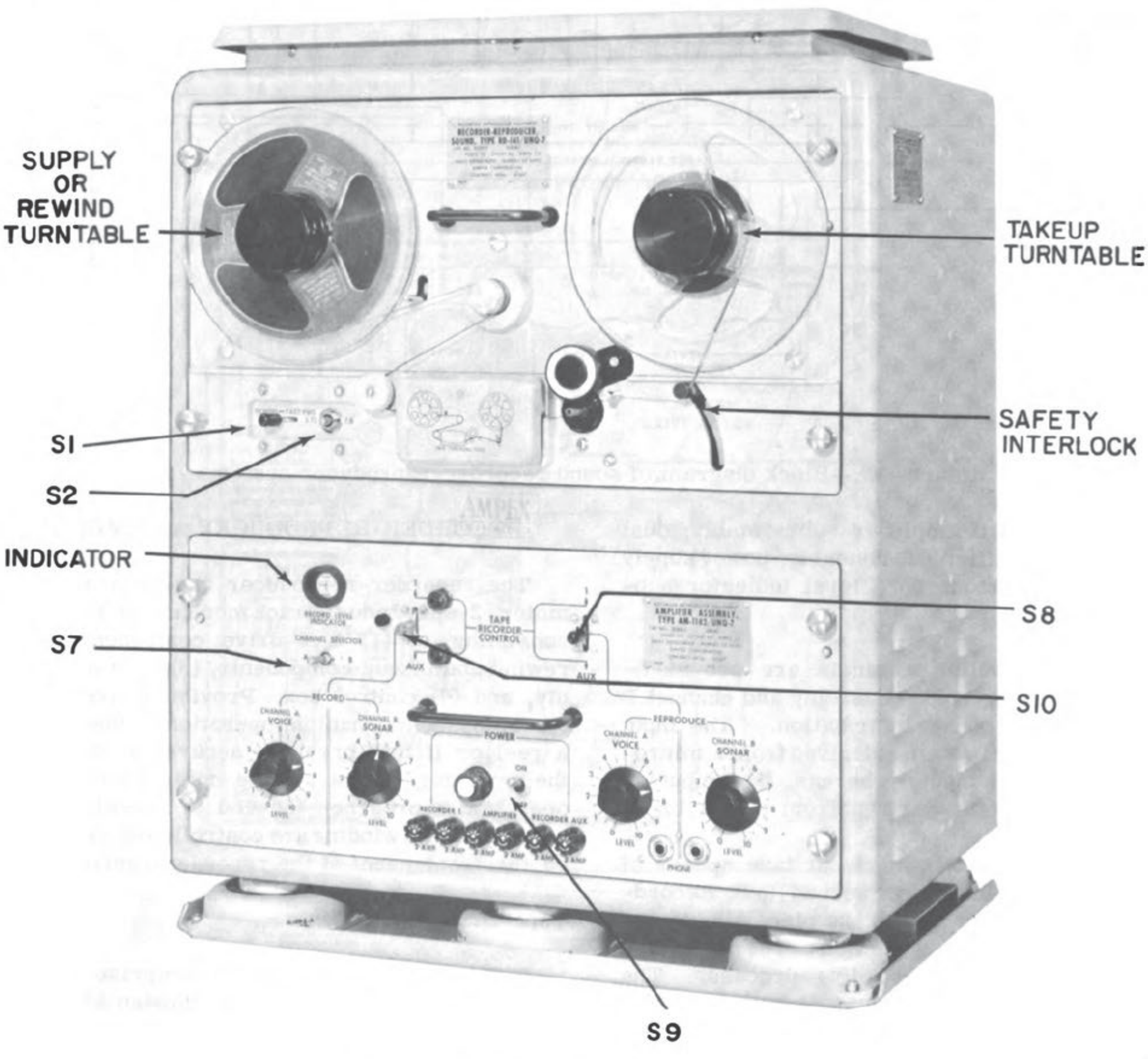

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Figure 7-6.—Sound recorder-reproducer set.

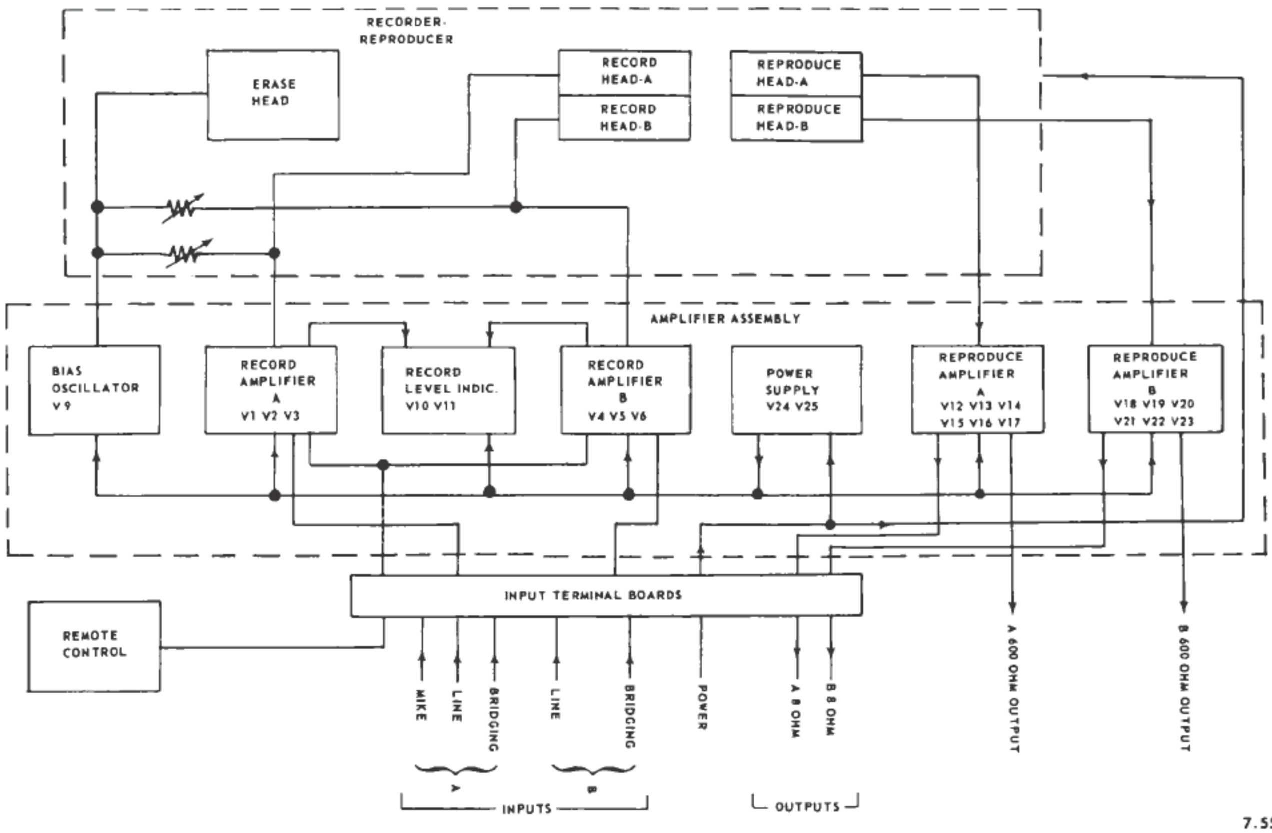


Figure 7-7.—Block diagram of sound recorder-reproducer system.

of a dual record amplifier subassembly, dual reproduce amplifier subassembly, power supply subassembly, and record level indicator subassembly.

Two information channels are provided—channel A is for voice recording and channel B for recording sonar information. The input signal to channel A can be derived from a microphone or line input, whereas the input to channel B must be derived from a line input.

Recordings can be made at tape speeds of 7 1/2 or 3 3/4 inches per second (ips). Recording and reproducing can take place simultaneously, or the recording function can be performed subsequent to the recording process. The equipment automatically erases prior recordings simultaneously on both channels as a new recording is made. Erasure can be effected without recording any new signal.

RECORDER-REPRODUCER ASSEMBLY

The recorder-reproducer assembly is a 3-motor, 2-speed, dual-track mechanism (fig. 7-8) consisting of (1) tape-drive components, (2) rewind and takeup components, (3) head assembly, and (4) control box. Provisions are made for stopping mechanical operation at the end of a reel or if tape breakage occurs, and to warn the operator at the remote control unit when operation approaches the end of a reel. Tape speed and fast winding are controlled by switches on the front panel of the recorder-reproducer.

Tape-Drive Components

The tape-drive components comprise a capstan drive motor, capstan, and capstan idler.

The capstan drive motor B3 (fig. 7-8) is a hysteresis synchronous motor having two stator windings (to provide the tape speeds of 7 1/2 and

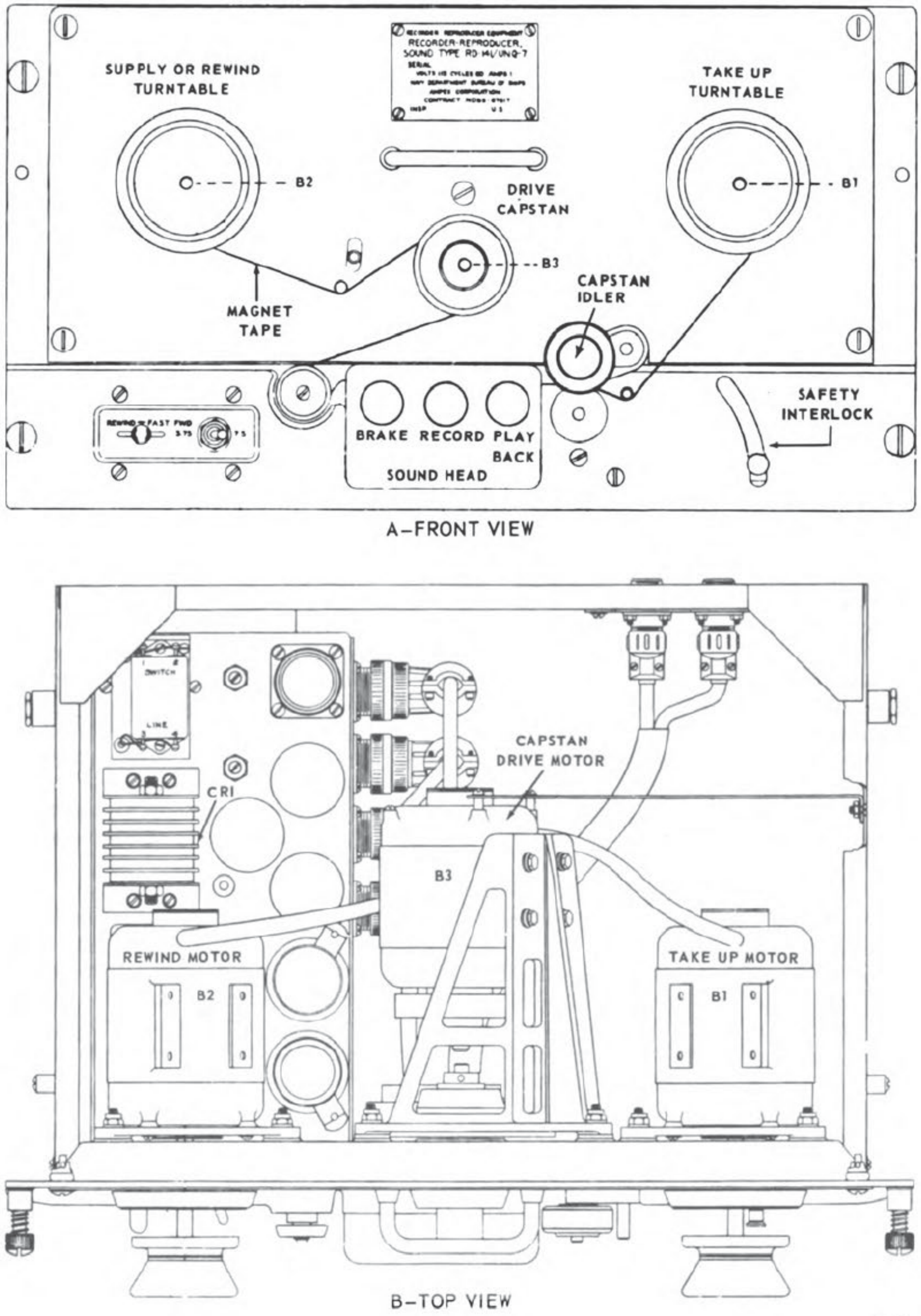


Figure 7-8.—Recorder-reproducer assembly.

3 3/4 ips), and a smooth-surface rotor of hardened magnet steel. The hysteresis losses of the rotor are utilized to produce the effective synchronous motor action. The load torque is produced by an angular shift between the axis of the rotating primary (stator) mmf and the axis of the secondary (rotor) magnetization. The torque is substantially the same from standstill up to synchronous speed. This type motor is limited to small sizes because of the small torque that can be derived from the hysteresis losses. When power is applied, the drive motor will start and the capstan will rotate.

The CAPSTAN is belt-driven from a flywheel pulley attached to the shaft of the drive motor. The drive belt tension is maintained by a spring-loaded pivot arm on which is mounted the CAPSTAN IDLER. The capstan idler consists of a rubber-tired idler wheel mounted on an arm which is attached to the shaft of a rotary solenoid. When the capstan idler solenoid is energized, it moves the idler arm against the capstan, providing a bearing surface for the capstan, which drives the magnetic tape at a constant speed.

A TAPE guide positions the tape vertically with respect to the head assembly. A REEL IDLER smooths out any transient variations in tape speed originating in the tape supply reel.

Rewind and Takeup Components

The rewind and takeup components are identical in construction. Each consists of an induction motor, brake drum, and turntable.

The rewind motor B2, and takeup motor B1, are so connected that when power is applied, one motor operates at full torque and the other at reduced torque. In the record or reproduce mode, A series resistor is placed in each (rewind and takeup) motor circuit to reduce the normal torque of the motors while optimum tape tension is obtained at each reel.

The reels of tape are isolated from each other by the capstan and capstan idler. The capstan pulls the tape from the supply reel, overcoming the difference in torque of the rewind motor, which provides hold-back tension. A tape loop will be thrown when any malfunction of the equipment allows the feed rate to exceed the takeup rate. If the loop is sufficiently large, or if tape breakage occurs, the safety switch arm will be released to actuate the safety switch, and stop the equipment.

In the FAST FORWARD MODE of operation, the series resistor is removed from the takeup motor circuit, and a resistor is placed in the rewind motor circuit. The takeup and rewind motors operate at full and reduced torques, respectively, and the capstan pulls the tape from the supply reel (on the rewind turntable) to the takeup reel (on the takeup turntable), overcoming the reduced torque of the rewind motor. The tape tension is proportional to the difference in the forces exerted at the periphery of the two reels.

In the REWIND MODE of operation, the foregoing procedure is reversed. The resistor is removed from the rewind motor circuit, and a resistor is placed in the takeup motor circuit. The rewind motor will operate at full torque, the takeup motor at reduced torque, and the tape will be pulled from the takeup reel to the supply reel being held under tension by the reduced torque of the takeup motor.

When the equipment is being operated in any mode of tape travel, the correct tape tension is determined by the power applied to the rewind and takeup motors. However, when power is removed from these motors the forces exerted on the tape are removed, and the tape tension must be maintained by the operation of the brakes.

The brakes consist of brake drums attached to the shafts of the takeup and rewind motors and brake bands equipped with high-tension and low-tension springs, which determine the braking force applied for each direction of rotation. The brake bands are held from contact with the brake drums by the brake solenoid when the equipment is operated under any mode. When power is removed from the equipment the solenoid is deenergized and allows the brake bands to move into contact with the brake drums. To avoid throwing tape loops as the tape comes to a stop, it is necessary that the braking force on the trailing turntable (turntable from which tape is being pulled) always be greater than that which is applied to the leading turntable (turntable which is taking up the tape). However, the braking differential must not be so great that the tape is in danger of being deformed or broken.

Head Assembly

The head assembly consists of an erase, record, and reproduce head (fig. 7-8). In the record or reproduce modes of operation, a point on the tape will pass over the erase, record, and reproduce heads in that order. The outer tracks of the record and reproduce heads are for channel A, and the inner tracks are for channel B. The erase head is full track, and thus erases the full width of the tape on both channels.

Control Box

The control box contains the electrical components associated with the control of tape motion. These components include the time delay relay, takeup relay, rewind relay, play relay, rectifier, and filter circuit to provide 115-volt, d-c power to operate the relays and solenoids. Also included are the resistors and capacitors for the takeup, rewind, and drive motors, the control switches, and reel-end warning mechanism. The rewind-fast forward switch S1, and tape speed switch S2, protrude through an opening in the front panel of the recorder-reproducer assembly (fig. 7-8).

AMPLIFIER ASSEMBLY

The amplifier assembly is divided into the (1) record, (2) reproduce, and (3) power supply subassemblies.

Record Subassembly

The record subassembly is illustrated by the block diagram in figure 7-9. It consists of the two record amplifiers, the AVC circuit for the channel B record amplifier, the bias oscillator, and the record level indicator.

The record amplifier (voice) for channel A (fig. 7-9) will accept inputs of 150-ohm microphone, 200,000-ohm balanced bridging line, and 600-ohm balanced line. The input connections depend on which type is desired. The microphone connects directly to the step-up input transformer T1. Resistors in the cabinet wiring (not shown) provide the matching impedance and signal attenuation for the 200,000-ohm balanced bridging line and the 600-ohm balanced line. The secondary of T1 is connected through the record level control R16, to the grid of V1, which is a triode-connected pentode to reduce noise. The plate of V1 is R-C coupled to the grid of V2. The signal from V2 is applied to the grid of the record output stage V3. The output stage V3, drives the record head through the record head relay (not shown).

A feedback resistor in the cathode circuit of V3 provides inverse feedback to the grid to furnish a constant current versus frequency characteristic in the amplifier output. A series resonant circuit (resonant at approximately 11 kc) is connected across the feedback resistor. As the signal frequency approaches this resonant condition, the resistor is shunted by the decreasing impedance of the resonant circuit, resulting in a higher signal amplitude at the plate of V3. Thus, high-frequency preemphasis is accomplished to compensate for the droop in the record- and reproduce-head characteristics caused by core losses, self-demagnetization of the tape at short wavelengths, and the wavelength approaching the gap dimensions. The signal fed to the record level indicator is picked up at the record level calibration potentiometer R21, between V2 and V3. The high-frequency record bias, derived from the bias oscillator V9, is adjusted in amplitude in the recorder-reproducer assembly and mixed with the signal to be recorded.

The record amplifier (sonar) for channel B (fig. 7-9) will accept inputs of 30,000-ohm balanced bridging line and 600-ohm balanced line. The input connections depend on the type desired. The 30,000-ohm balanced bridging input is connected to the primary of the input transformer T2, through isolating resistors in the cabinet wiring (not shown). The balanced 600-ohm line is connected across a matching resistor (not shown) and then through the same isolating resistors to the input transformer T2.

The signal at the balanced secondary of T2 is applied through the dual record level control R29A and R29B, to the grids of tne push-pull amplifier input stage V4 and V5. The output of V4 and V5 is transformer coupled to the grid of the record output stage V6. Low-frequency compensation is employed in the plate circuit of the push-pull input stage V4 and V5, to extend the l-f recording capabilities of this amplifier.

The output signal of V6 is fed through the record head relay K6 (not shown), mixed with the high-frequency record bias derived from the bias

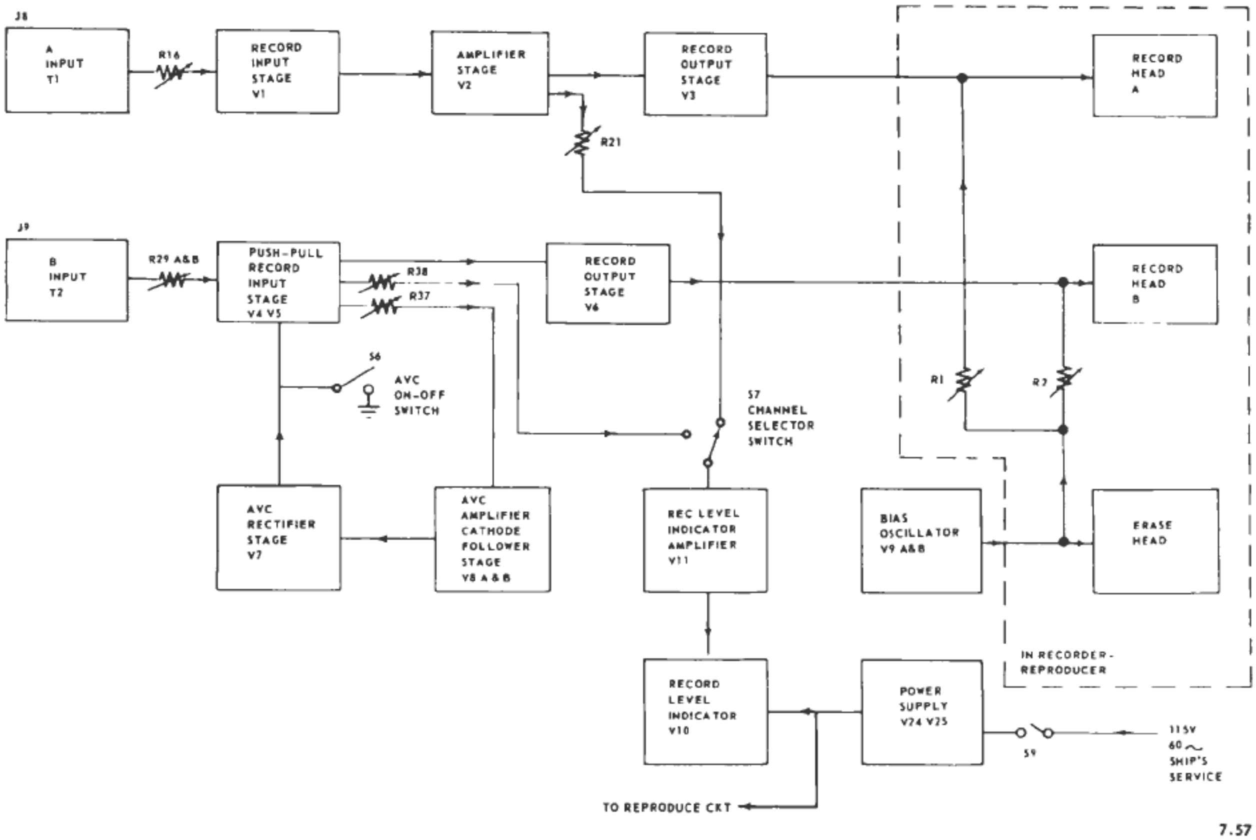


Figure 7-9.—Block diagram of record circuit.

oscillator V9, adjusted in the recorder-reproducer assembly, and delivered to the record head. Two signals, one to be delivered to the record level indicator V11, and one to be delivered to the AVC circuit V8, are adjusted at the potentiometers R38 and R37, respectively. A series resonant circuit across the V6 cathode inverse feedback resistor provides high-frequency preemphasis in the same manner as the channel A record amplifier, V3, previously described.

The AVC circuit (fig. 7-9) derives its signal voltage from the potentiometer R37, across the secondary of the V4-V5 output transformer in the channel B record amplifier. The adjusted voltage is amplified by V8B and fed to the grid of the cathode follower stage V8A. The output of V8A supplies the signal voltage to the AVC detector stage V7, which is a twin diode rectifier, the sections of which are connected in parallel. The rectified AVC voltage is filtered and applied to the grids of the push-pull input stage, V4 and V5, of the channel B record amplifier to limit its gain in accordance with the amplitude of the input signal.

The switch S6, is the AVC on-off switch (fig. 7-9). When S6 is in the OFF position, the grids of the push-pull input stage, V4 and V5, of the channel B record amplifier are returned to ground through the dual record level control, the AVC voltage is shorted to ground, and thus the AVC circuit does not operate. The AVC circuit utilizes a voltage-delay feature so that the AVC action does not function until the signal reaches a certain preadjusted amplitude. This action is accomplished by applying a positive bias voltage to the cathode of the detector stage V7, so that it will not conduct, and consequently cannot develop the AVC voltage until the peak signal exceeds the bias (delay) voltage.

The bias oscillator V9 (fig. 7-9) provides both the high-frequency record bias and the

erase current. It consists of twin triode V9A and V9B, which is a conventional Colpitts push-pull oscillator operating at a nominal frequency of 100 kc. The exact frequency, however, is not critical. Any signal at the grid of V9A is amplified in the plate circuit, coupled to the grid of V9B, and appears at the plate of V9B. The signal is then coupled back to the grid of V9A in phase with the original signal to produce positive feedback and oscillation.

The energy from V9 is taken from the secondary of the associated output transformer (the primary of which is the oscillator tank coil) through the record head relay K6 (not shown) to the erase head. The record bias current is adjusted and delivered to the record heads (fig. 7-9) through potentiometer R1 (channel A) and through potentiometer R2 (channel B) located in the recorder-reproducer assembly. Plate voltage is applied only when the equipment is operated in the record mode. The noise balance control (not shown) is common to both grids of V9, and is adjusted to eliminate distortion in the oscillator waveform, which would cause a d-c component in the record head and tend to magnetize the head.

The record level indicator (fig. 7-9) consists of a cathode-ray tube V10, and a signal amplification stage V11. The signal voltage for the record level indicator is derived from the potentiometer R21 (channel A) and potentiometer R38 (channel B) connected in the grid circuits of the final stage of each record amplifier before the high-frequency preemphasis is applied. Potentiometers R21 and R38 are used to calibrate the record level indicator. The signals are routed to the channel selector switch S7, to select the channel to be visually monitored by the level indicator.

An individual signal is fed from switch S7 to the grid of the amplifier V11, the output of which is fed to the vertical deflection plates of V10. The horizontal sweep for V10 is provided by a sinusoidal, 60-cycle voltage (approximately 10 volts) derived from the secondary of the power supply transformer. This arrangement provides a sweep of approximately 1/8 inch to prevent burning of the phosphor on the tube, and to furnish width to the cathode-tube presentation. The half-wave rectifier V24, supplies -600 volts, direct current to the grids of V10, and the full-wave rectifier V25, supplies plate voltage to V11 when the power switch S9, is in the ON position.

External adjustments to the level indicator can be made by means of controls located on the back of the record level indicator subchassis. These controls include horizontal centering, vertical centering, focus, and intensity.

Reproduce Subassembly

The reproduce subassembly is illustrated by the block diagram in figure 7-10. It consists of two identical reproduce amplifiers, one for channel A, and one for channel B.

The reproduce amplifier for channel A (fig. 7-10) consists of a 6-stage, resistance-coupled audio amplifier with a transformer-coupled push-pull output. The leads from the reproduce head enter the amplifier assembly at J11 and connect to contacts of the reproduce head relay K10 (not shown). These relay contacts connect the reproduce head to the grid of the input stage V12A, of the reproduce amplifier.

A reproduce equalization circuit consisting of a relay (K9) and either of two resistors, depending on the position of the tape speed switch S2 (fig. 7-6), is included in the plate circuit of V12A. Relay K9 is controlled by the tape speed switch on the recorder-reproducer and selects the appropriate equalization circuit for the speed involved.

The input stage V12A, is followed by V12B, V13, the reproduce level control R92, triode V14, driver stage V15A, phase inverter stage V15B, push-pull output V16 and V17, and the output transformer. A negative feedback of approximately 10 db is obtained from the tertiary winding on the output transformer. The tertiary winding is connected through R95 to the cathode of V14.

The cathodes of V15A and V15B are not grounded directly, but are fed to contacts of the reproduce switch S8 (fig. 7-6) to ground. Thus, when S8 is in the neutral (middle) ungrounded position the reproduce amplifier is disabled to prevent the reproduction of any material when the tape is operated in the fast forward or rewind mode. Plate voltages are applied to all stages when the power switch S9, is in the ON position. The output transformer is connected to two parallel outputs, one of which is a 2-circuit phone plug on the front panel of the amplifier assembly and the other output is on the terminal boards in the cabinet.

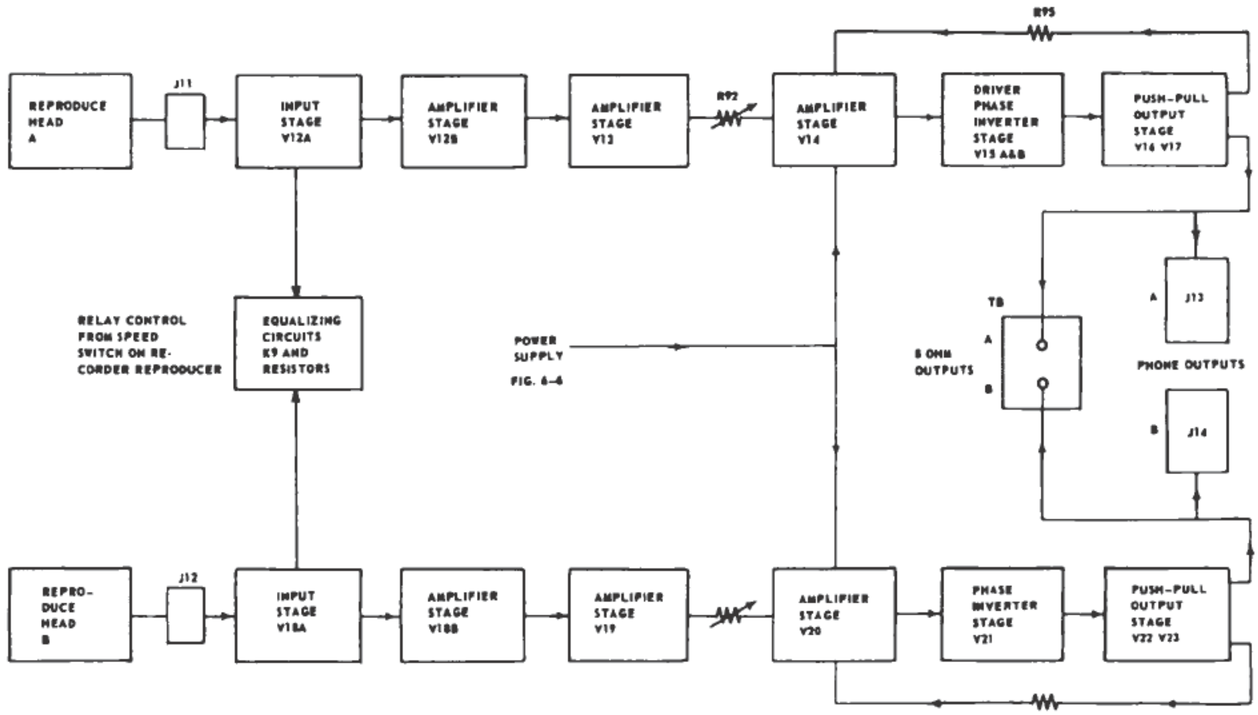


Figure 7-10.—Block diagram of reproduce circuit.

Power Supply Subassembly

The power supply furnishes all the power requirements for the entire equipment except for the 115-volt, d-c power supplied by the rectifier CR1 (fig. 7-8) in the control box to operate the solenoid and relay in the recorder-reproducer assembly.

The a-c power input to the power transformer is controlled by the on-off power switch S9 (fig. 6-5) located on the front of the amplifier assembly. The half-wave rectifier V24 (fig. 7-9) supplies the -600 volts d-c for the cathode-ray tube V10, in the record level indicator. This voltage is filtered. The full-wave rectifier V25, supplies the plate voltage for all the other tubes in the amplifiers. This voltage is also filtered. Additional resistor-capacitor filter sections are provided as decoupling networks for various circuits in the amplifiers.

OPERATION

The operating controls and indicators for the recorder-reproducer set are located on the front panels of the recorder-reproducer assembly and on the amplifier assembly (fig. 7-6). Two headphone jacks, one for channel A and one for channel B, are located on the front panel of the amplifier assembly. High impedance headphones can be plugged into these jacks to provide monitoring of the reproduce output of either channel.

The record switch S10, and the reproduce switch S8, each has two positions designated 1 and AUX. The AUX position, and the AUX indicator are not normally activated but are provided for use if an auxiliary recorder-reproducer is added to the system.

Recording

To place the equipment in the record mode, install a full reel of magnetic tape on the left-hand (supply or rewind) turntable and an empty reel on the right-hand (takeup) turntable (fig. 7-6). The tape threading path between the reels is engraved on the front panel of the recorder-reproducer assembly. Hold the tape by one finger on the hub of the takeup reel and rotate

the reel several revolutions in a counterclockwise direction to anchor the tape on that reel. Continue turning the takeup reel until the tape tension holds the safety arm in the upper portion of its clearance slot.

Schematic diagrams of the amplifer and recorder-reproducer assemblies are shown in figures 7-11 and 7-12, respectively.

When S9 (fig. 7-11) is placed in the ON position, a-c power is applied through F5 and F6 to the T6 primary. It is also applied through F2, terminals 6 and 5 of J15, terminal G of J2, through terminals 4 and 6 of S2, to B3, returning via terminal A of J2 to F1. Motor B3 will start. The circuit to CR1 is also completed from F2 and F1 via terminals N and A on J2.

The d-c control power circuit is from F2 to terminal N on J2, CR1, and S5 in the operated position where the circuit then branches. One branch extends to S1 via contacts 8-9 of K4. The other branch extends to contacts 8-9 of K2 and K3 and contacts 4-5 of K1 to terminal L of J2. From terminal L the circuit branches to contact 1 of S10, contact 7 of S8, and contact 4 of K7.

Next, connect a signal, corresponding to that which will normally be recorded, to the inputs of either or both channels and place the channel selector switch S7 (fig. 7-6) in either A or B position to select the appropriate channel on which the record level is to be set. Observe the vertical amplitude of the signal on the record level indicator. If necessary, adjust the appropriate record level control until the signal peaks occupy the space between the upper and lower horizontal lines. Reverse the position of the channel selector switch S7, and repeat the foregoing procedure for the other channel.

The equipment is now ready to record simultaneously on both channels at normal operating level. To start the recording process, hold the record safety interlock to the left (fig. 7-6) and place the record switch S10, in position 1. The tape will start in motion and the record indicator 1 on the amplifier assembly will light (fig. 7-6). Reset the record level control(s) if necessary.

When the record switch S10 (fig. 7-11) is placed in position 1, contacts 1-2 complete the d-c circuit to the coil of relay K7 from terminals L and A on J2. Contacts 4-12 of relay K7 complete the circuit across terminals L and M of J2, through the coil of play relay K4 (fig. 7-12), and through the capstan idler solenoid, L1, causing the idler to force the tape against the capstan and start tape motion. Contacts 5-6 of relay K7 (fig. 7-11) complete the circuit to apply a-c power to the record indicator in the remote control unit (not shown) and contacts 1-11 break to open the circuit to the standby indicator in the remote control unit. Contacts 10-14 and 8-9 of relay K7 complete the circuit to apply B+ power to the final stages of the record amplifiers and to the bias oscillator. Contacts 7-13 of relay K7 complete the circuit to light the record 1 indicator.

When the play relay K4 (energized through contacts 4-12 of relay K7) operates, contacts 7-8 complete the d-c circuit to the brake solenoid, L2, which pulls the brakes from contact with the brake drums (fig. 7-12). Contacts 5-6 of relay K4 complete the a-c circuit to the takeup motor B1, and the rewind motor B2, through R4 and R6, and the normally closed controls 4-5 of relays K2 and K3, respectively.

When the reel-end warning switch S3 (fig. 7-12) is actuated by the angle of the tape as it leaves the supply reel, the flasher switch motor FL1, is energized through contacts 5-6 of play relay K4 and contacts 1-2 of switch S3. The flasher switch motor intermittently opens and closes the circuit to the record indicator on the remote control unit, causing the indicator to flash on and off.

The recording process can be stopped at any time by returning the record switch S10, to the NEUTRAL (middle) position (fig. 7-6). It is not necessary to manipulate the record safety interlock. Thus, the recording function can be started or stopped whenever it is desired through the run of a reel, with the equipment returning to the standby condition whenever the record switch S10, is in the neutral position. The tape-motion components will be automatically deactivated at the end of a reel.

Recording from Remote Control Unit

The remote control unit (fig. 7-6) provides the remote operator with facilities for placing the equipment in the record mode of operation from the standby condition. The standby indicator denotes that power is applied and that tape is threaded at the recorder-reproducer. It does not denote that proper tape speed is selected or that the recording levels have been adjusted. The standby indicator will not light when power is not applied, or when the tape is not properly threaded, or if the equipment is

being used to reproduce a previously recorded tape.

The record indicator on the remote control unit denotes that the equipment has been placed in the record mode of operation either at the remote control unit or at the recorder-reproducer. The record indicator will start flashing on and off approximately five minutes before the end of a reel of tape. This action will occur only when the end of the reel is approached with the equipment in the record mode. The record indicator will be extinguished and the standby indicator will light.

The standby record switch on the remote control unit (fig. 7-6) simply parallels the record switch S10, on the recorder-reproducer set. Thus, if either switch is in the RECORD position, it is not possible to stop the record mode at the other location. It is possible to place the equipment in the record mode when a previously recorded tape is being reproduced. Therefore, the standby record switch on the remote control unit should only be moved from its STANDBY position when the standby indicator is lighted. A previously recorded tape will be erased if run with the equipment in the record mode.

Reproducing

To place the equipment in the reproduce mode, operate the power switch S9 to the ON position and the tape speed selector switch S2 (fig. 7-6) to the speed position in which the recording was made. When the reproduce switch S8 is in position 1, tape motion will start and the reproducing function will be in process on both channels simultaneously.

When the reproduce switch S8 is in position 1, contacts 7-8 (fig. 7-11) complete a d-c circuit across terminals L and M on J2 through the coil of the play relay K4, and the capstan idler solenoid L1 to terminal A on J2 (fig. 7-12). The capstan idler forces the tape against the capstan to start tape motion. The operation of play relay K4 is the same as that described for the recording function. The reproduce switch S8 also opens the circuit through contacts 1-3 to extinguish the standby indicator at the remote control unit (not shown).

When the tape speed selector switch S2 is in the 7 1/2 speed position (fig. 7-12), the circuit to the equalization relay K9 is interrupted at contacts 1-2, and K9 is not energized. Contacts 4-5 and 8-9 of relay K9 (fig. 7-9) select the 7 1/2 speed equalization circuits for the reproduce amplifiers. When the tape speed switch S2 is in the 3 3/4 speed position, contacts 1-2 complete a circuit through the equalization relay K9, via terminals S and H on J2 and contacts 10 and 11 on S8. Contacts 5-6 and 7-8 of relay K9 select the 3 3/4 speed equalization circuits for the reproduce amplifiers.

Contacts 4-5 of the reproduce switch S8 provide the ground return for the cathodes of the phase inverter stages V15A and V15B of the reproduce amplifiers.

To stop the reproduce function, return the reproduce switch S8 to the NEUTRAL position. Thus, the reproduce function can be started and stopped as desired through the run of a reel, with the equipment returning to the standby condition when the reproduce switch is in the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

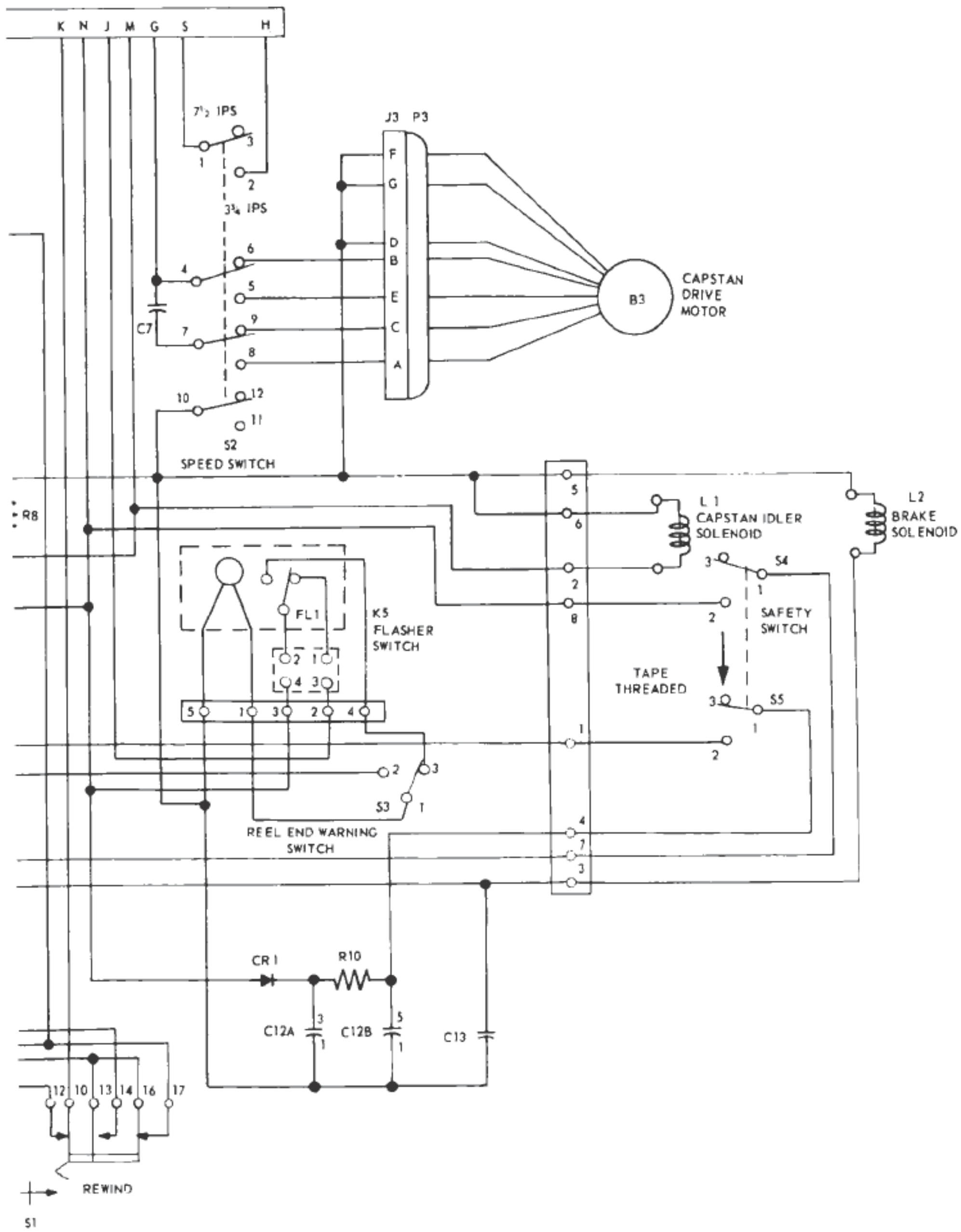
Simultaneously Recording and Reproducing

To record and reproduce simultaneously, place the equipment in the record mode. Operate the power switch S9 (fig. 7-6) to the ON position and the tape speed selector switch S2 in the appropriate position to select the desired recording speed.

Connect a signal corresponding to that which will normally be recorded to the inputs of either or both channels and place the channel selector switch S7 in either the A or B position to select the appropriate channel on which the record level is to be set. Observe the vertical amplitude of the signal on the record level indicator, and, if necessary, adjust the appropriate record level control. Reverse the position of the channel selector switch S7, and repeat the check on the amplitude of the signal.

The equipment is now ready to record simultaneously on both channels at normal operating level. To start the recording function, hold the record safety interlock to the left and place the record switch S10, in position 1. The tape will start in motion, and the record indicator 1 will light. Reset the record level control if necessary.

Place the reproduce switch S8 in position 1. The information being recorded on both tracks of the tape will now be reproduced. The tape passes over the erase, record, and reproduce



K N J M G S H
7½ IPS
3¾ IPS
J3 P3
CAPSTAN DRIVE MOTOR
B3
C7
S2
SPEED SWITCH
R8
L 1
CAPSTAN IDLER SOLENOID
L2
BRAKE SOLENOID
K5
FLASHER SWITCH
FL1
S4
SAFETY SWITCH
TAPE THREADED
S5
S3
REEL END WARNING SWITCH
CR1
R10
C12A
C12B
C13
REWIND
S1

7.60

.y.

heads in succession. Adjust the reproduce level controls for the desired output level on both channels.

Acoustical feedback may result when recording from a microphone and simultaneously reproducing from a loudspeaker at the same location. This condition can be prevented by proper placement of the microphone and loudspeaker and appropriate adjustment of the reproduce level control so that little or none of the loudspeaker output is fed back into the microphone. A slight time delay will be noticed between the introduction of the input signal and the acoustical output of that signal at the loudspeaker because of the placement of the record and reproduce heads and the consequent tape-travel time between the two heads.

To stop either the record or reproduce function, return the appropriate switch to the NEUTRAL position. To stop both the record and reproduce functions (and tape motion) return both the record and reproduce switches S10 and S8 to the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

Rewind and Fast Forward Operation

If the tape is threaded on the recorder-reproducer and is not in motion, it can be moved rapidly in either the forward (fast forward) or reverse (rewind) direction by placing the rewind-fast forward switch S1 in the appropriate position (fig. 7-6). The tape motion can be stopped by returning this switch to the NEUTRAL position. The tape-motion components will be automatically deactivated at the end of a reel.

If the tape is in motion in the record or reproduce mode when the fast forward rewind switch S2 is placed in other than the NEUTRAL position, normal operation will continue until the record switch S10, and reproduce switch S8 are returned to their NEUTRAL positions. The tape motion will then immediately go into the fast winding mode dictated by the position of the fast forward rewind switch S1.

If either the record switch S10 or reproduce switch S8 is placed in position 1 when the tape is in motion in the rewind or fast forward mode, the rewind or fast forward operation will continue until the rewind-fast forward switch S1 is returned to the NEUTRAL position. The tape will then come to a stop, and after a delay of approximately three seconds, it will start in response to the setting of the record switch S10 or the reproduce switch S8. The delay is introduced to prevent the tape from breaking or stretching, which would probably occur if the capstan idler should engage the capstan with the tape in rapid motion.

When the fast forward rewind switch S1 (fig. 7-12) is in the FAST FORWARD position, contacts 7-9 open the circuit to extinguish the standby light on the remote control unit (not shown); contacts 1-2 energize the takeup relay K2; and contacts 4-5 complete a circuit to energize the time-delay relay K1, and allow C4A and C4B to charge.

When the takeup relay K2 operates, contacts 8-9 open the circuit (via terminals A and L on J2) to the record relay K7 in the amplifier assembly (fig. 7-11), to the play relay K4 and to the capstan idler solenoid L1 (fig. 7-12). Contacts 7-8 (relay K2) energize the brake solenoid L2, which pulls the brakes from contact with the brake drums. Contacts 4-5 remove R4 from the circuit of the takeup motor B1. Contacts 5-6 place the takeup motor B1 directly across the a-c line (terminals A, and N of J2) and the rewind motor B2, across the a-c line in series with R9. This action causes the takeup motor B1 to operate at full torque, and the rewind motor B2 to operate at reduced torque.

The time-delay relay K1 remains energized by the discharge of C4A and C4B for about three seconds after the fast forward rewind switch S1 is placed in the NEUTRAL position (fig. 7-10). Time-delay relay K1 then operates to open its contacts 4-5, which are in series with the record relay K7 (fig. 7-11), play relay K4, and the capstan idler solenoid L1 (fig. 7-12). Thus, if either the record switch S10 or the reproduce switch S8 is placed in its position 1 while the equipment is in the fast winding mode, and the fast foward rewind switch S1 is then placed in its NEUTRAL position, the 3-second delay will allow the fast-moving tape to stop before the capstan idler forces the tape against the capstan and thereby avoids breaking or stretching the tape.

When the fast forward rewind switch S1 (fig. 7-12) is in the REWIND position, contacts 10-12 open the circuit to extinguish the standby indicator at the remote control unit (not shown). Contacts 13-14 complete a circuit to the rewind relay K3, and contacts 16-17 complete a circuit

to the time-delay relay K1 allowing C4A and C4B to charge.

When the rewind relay K3 operates, contacts 8-9 open the circuit to the record relay K7 (fig. 7-11), play relay K4 (fig. 7-10), and the capstan idler solenoid L1, via terminals L and M of J2. Contacts 7-8 of K3 complete a circuit to energize the brake solenoid L2, which pulls the brakes from contact with the brake drums. Contacts 4-5 remove R6 from the circuit of the rewind motor B2. Contacts 5-6 place the rewind motor B2, directly across the a-c line (terminals A and N of J2) and the takeup motor B1, across the a-c line in series with R9. Thus the rewind motor B2 and the takeup motor B1 will operate at full and reduced torques, respectively. The time-delay relay K1 provides the same delaying action previously described.

Cueing and editing can be accomplished at fast speed by changing the fast forward rewind switch S1 back and forth between the REWIND and FAST FORWARD positions. It is not necessary to allow the tape to slow down or come to a stop because the shuttling process does not damage the tape or equipment. The reproduce switch S8 may be placed in position 1 during the shuttling process to provide aural (by ear) monitoring. However, do not allow the fast forward rewind switch S1 to pause in its NEUTRAL position for more than the 3-second delay period because the equipment will automatically enter the reproduce mode.

Erasing

Erasure of a previously recorded tape without recording new information may be accomplished by installing the tape on the recorder-reproducer, turning both the record level controls to the full counterclockwise position, and running the tape in the record mode at a tape speed of 7 1/2 ips.

MAINTENANCE

If a tape recorded on the sound recorder-reproducer set does not reproduce properly, the trouble may be in either the record or reproduce circuits. Isolating the malfunctioning circuit can be easily accomplished by reproducing a standard alignment tape. If the reproduction is normal the trouble is in the components associated with the record circuit. If the same trouble is experienced the trouble is in the components associated with the reproduce circuit.

Another method of determining whether the record or reproduce circuits is at fault is to simultaneously record the same signal on both channels. Rewind the tape and reproduce it, observing the output of both channels. Then, without rewinding the tape, transpose the reels by placing the supply reel on the takeup turntable and the takeup reel on the supply turntable. This transposition will orient the reels so that the signal recorded on one channel will be reproduced on the other channel. Reproduce the tape, comparing the output of each channel with the results noted on the previous run. If the same channel exhibits the subnormal indication the fault is in the reproduce circuit. If the trouble now appears at the output of the other channel the fault is in the record circuit.

When the faulty circuit is identified, the trouble can be further isolated by following the alignment procedures described in the manufacturer's technical manual furnished with the equipment. As previously stated, the recorder-reproducer assembly and the amplifier assembly can be extended from the cabinet and rotated so that the test points and components are readily accessible. It should not be necessary to remove these assemblies from the cabinet for ordinary servicing.

If the set will reproduce normally, but in the record mode it will not erase and will not record, even though the monitor indicators show normal input to the microphone, the trouble may be in the record head.

While this head is magnetized by the signal input during the recording process, it pulls particles of iron oxide off the magnetic tape. These particles gradually build up and in time will short-circuit the magnetic air gap of the record and erase head.

This accumulation can be removed by cleaning with a pipe cleaner moistened with cleaning or lighter fluid. This trouble may be avoided by cleaning the heads periodically.

QUIZ

1. Name the three basic techniques of recording and reproducing sound.
2. Name the four media normally used for recording purposes.
3. What two processes are employed in mechanical recording to preserve the sound pattern on the recording medium?
4. In mechanical recording, what process is used to preserve the sound patterns on (a) disks, and (b) films?
5. Name the five components necessary to mechanically record sound.
6. In mechanical disk recording, what is the action of the stylus as a result of the electrical signal received by the recording head?
7. In mechanical recording, what does the (a) frequency and (b) volume of the sound being recorded determine with respect to the lateral swings of the stylus?
8. Name the two methods of photographically recording sound.
9. What is the action of the recording head in the magnetic recording technique?
10. What is the direction and speed of the wire or tape during magnetic playback with respect to magnetic recording?
11. In magnetic recording, what is the purpose of the a-c bias on which the audio signal is superimposed and applied to the recording head?
12. How is the recorded sound track erased on a magnetic recording medium?
13. Name the three major components that comprise the sound recorder-reproducer set.
14. Name the four components that comprise the recorder-reproducer assembly.
15. How is the proper tape tension provided when operating the equipment in the fast forward or rewind mode?
16. How is tape tension provided when power is removed from the rewind and takeup motors?
17. Name the three heads that comprise the head assembly.
18. Name the three subassemblies that comprise the amplifier assembly (fig. 7-9).
19. Name the five major components that comprise the record subassembly (fig. 7-9).
20. Name the three inputs that the record amplifier (voice) for channel A will accept.
21. Name the two inputs that the record amplifier (sonar) for channel B will accept.
22. From what source is the signal voltage derived for V8 in the AVC circuit (fig. 7-11)?
23. Trace the signal voltage derived from R37 across T3 in the channel B record amplifier through the AVC circuit to the input of V4 and V5 in the channel B amplifier (fig. 7-11).
24. How is the time-delay feature accomplished in the AVC circuit (fig. 7-11)?
25. How is the record bias current from the bias oscillator (fig. 7-11) adjusted and delivered to the channel A and channel B record heads in the recorder-reproducer assembly (fig. 7-12)?
26. What is the source of the signal voltage for the record level indicator (fig. 7-11)?
27. What is the purpose of switch S7(fig. 7-11)?
28. What is the source of voltage applied to (a) the grids of V10 and (b) the plate of V11 (fig. 7-11)?
29. What components of the equalization circuit are connected to the plate circuit of V12A (fig. 7-11) when the tape speed switch S2 (fig. 7-12) is in the 7 1/2 speed position and relay K9 is deenergized?
30. What is the source of the 115-volt, d-c power for the operation of the solenoids and relays in the recorder-reproducer assembly (fig. 7-12)?
31. What is the purpose of R111, C68, and C67 in the power supply (fig. 7-11)?
32. What is the purpose of C69, L5, and C60C in the power supply (fig. 7-11)?
33. When the power switch S9 is placed in the ON position (fig. 7-6), where is a-c power applied in the (a) power supply (fig. 7-11), and (b) recorder-reproducer assembly (fig. 7-12)?
34. What is the function of channel selector switch S7 (fig. 7-6)?
35. What is the function of the record switch S10 (fig. 7-6)?
36. What condition is denoted when the standby indicator is lighted at the remote control unit (fig. 7-6)?

37. What condition is denoted when the record indicator is lighted at the remote control unit (fig. 7-6)?

38. If either the standby record switch on the remote control unit or the record switch S10 on the recorder-reproducer set is in the REMOTE position, (a) is it possible to stop the record mode at the other location and (b) why?

39. (a) What is the mode of operation of the recorder-reproducer and (b) what channels are used when a reel of tape is properly threaded on the recorder-reproducer (fig. 7-6), the power switch S9 is in the ON position, the tape speed switch S2 is in the appropriate speed position, and the reproduce switch S8 is in position 1?

40. When the tape speed switch S2 is in the 7 1/2 speed position (fig. 7-12), (a) what is the condition of the equalization relay K9 and (b) what are the equalization components connected to the plate circuit of V12A (fig. 7-11)?

41. When the tape speed switch S2 is in the 3 3/4 speed position, (a) what is the condition of the equalization relay K9 and (b) what are the equalization components connected to the plate circuit of V12A?

42. What is the action of the time-delay relay, K1 (fig. 7-12) if either the record switch S10 or the reproducer switch S8 is placed in its position 1 while the equipment is in the fast winding mode and fast forward rewind switch S1 is then placed in its NEUTRAL position?

CHAPTER 8

SOUND MOTION PICTURE SYSTEMS

In addition to sound, a knowledge of light and lenses is essential for a clear understanding of the theory involved in sound motion picture projection.

PRINCIPLES OF LIGHT

Light is radiant energy capable of affecting the eye to produce vision. Light is also defined as a form of energy that results when minute particles of a body are set into extremely rapid vibration. This vibration is usually caused by intense heat and is accompanied by extremely high temperatures.

The sun and stars are natural sources of direct radiation, both visible and invisible; whereas the moon and planets are natural sources of indirect radiation by reflection. The incandescent electric lamp is an artificial source of direct radiation that gives off light because of the high temperature of its filament, which is heated by an electric current.

PROPAGATION OF LIGHT

Light is a form of wave motion propagated through certain uniform media or through empty space with an exceedingly great, but finite and measurable, velocity (fig. 8-1). A light wave is a TRANSVERSE wave the vibrations of which are perpendicular to the direction of propagation, as illustrated in figure 8-1, A. The amplitude of a light wave, like that of a water wave, is the height of the crest or the depth of the trough.

The WAVELENGTH λ is the distance between successive points in identical stages of motion of a light wave. Wavelengths are indicated in figure 8-1, A, as the distance from the crest of one wave to the crest of the next wave.

The WAVEFRONT is a line connecting particles of the medium over which the disturbance is momentarily uniform. Wavefronts are indicated in figure 8-1, A, by portions of concentric circles. Thus, a wave emitted from a point source S with equal velocity in all directions would have a succession of expanding spherical wavefronts.

A light RAY is a straight line extending in the direction of propagation from the light source. The term "ray" can be used to refer to the light itself or to the lines that represent its path. A wavefront moving outward is assumed to be perpendicular to the ray a short distance from the light source.

A parallel BEAM of light is a bundle of parallel rays (fig. 8-1, B); a CONE of light is a narrow bundle of diverging rays (fig. 8-1, C); and a PENCIL of light is a narrow bundle of converging rays (fig. 8-1, D).

The rays of light from a large source such as the sun diverge very little, and for practical purposes are considered to be parallel. On the other hand, the rays of light from artificial sources, such as incandescent and arc lamps, spread out as they are propagated through space and diverge as they move farther from the source. For practical purposes these rays are considered as originating from a point source.

VELOCITY OF LIGHT

Light travels at a definite speed in any one medium. The speed of light is approximately 186,000 miles per second in a vacuum, is slightly lower in air, and appreciably lower in water, glass, and other media. The velocity of light is related to its frequency and wavelength in a formula similar to that relating the velocity of sound to its associated frequency and wavelength.

$$v = f\lambda.$$

CHARACTERISTICS OF LIGHT

A beam of light must cover a greater area as it moves farther from the source because the light from a point source spreads out in all directions. Thus, the intensity (brightness) of light decreases with distance. The inverse-square law applies to this decrease in intensity

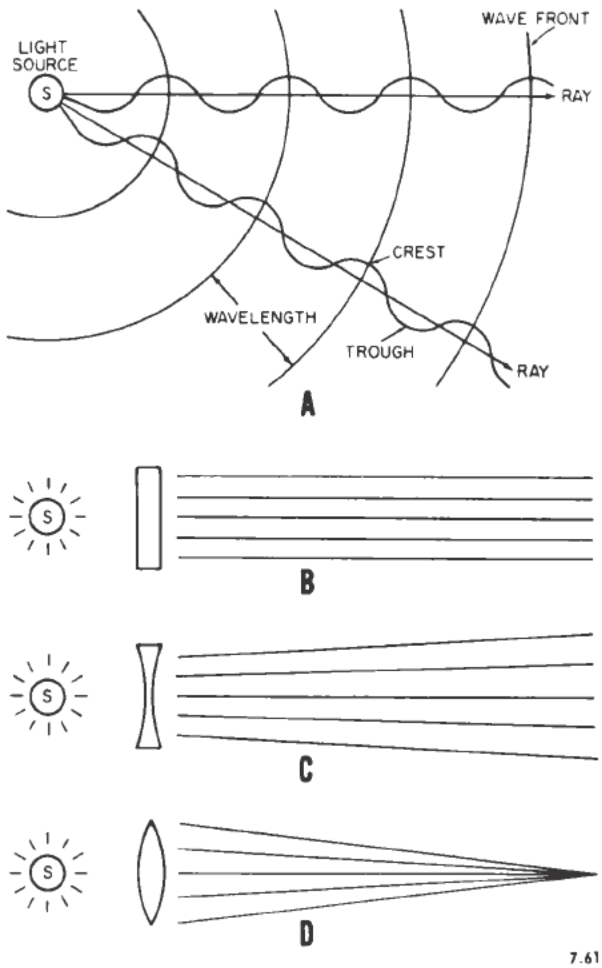


Figure 8-1.—Propagation of light waves.

with an increase in distance—that is, the light intensity is inversely proportional to the square of the distance from the source. The eye cannot form a quantitative estimate of the degree of brightness because the pupil opens or closes to receive more or less light according to the intensity of illumination.

Certain kinds of light produce the sensation of color. The color of light is produced by the different light frequencies that have different effects on the optic nerve. The color is determined by the frequency of vibration and the associated wavelength of the light wave.

The solar spectrum contains the following colors in the order of their wavelength:

*1. Infrared	4. Yellow
2. Red	5. Green
3. Orange	6. Blue
7. Violet	*9. X rays
*8. Ultraviolet	*10. Gamma rays
*11. Cosmic rays	

*Not visible to the naked eye.

At one extreme, red is produced by the longest waves (lower frequency) and at the other extreme, violet is produced by the shortest waves (higher frequency).

An object reflects the light associated with its own color. Thus, an object is red if it reflects red light, or blue if it reflects blue light. Sunlight contains all the colors of the visible spectrum. Colored objects look natural in sunlight because each reflects that part of the spectrum associated with its own color and absorbs the remaining light.

A brilliant red object in sunlight looks gray when illuminated by a sodium vapor light because there are no red rays in sodium vapor. The object loses its brilliant color because it absorbs the yellow light of the sodium vapor lamp and cannot reflect its natural color in the absence of the red rays.

PROPERTIES OF WAVE MOTION

Two important properties of wave motion are reflection and refraction. Both light waves and sound waves have these properties. Sound waves were discussed earlier in the text, therefore, only light waves will be discussed here.

REFLECTION

Light waves, like sound waves, can be reflected and refracted. When a light ray strikes the surface of an opaque object, some of the light is absorbed and converted into heat, and the remainder is reflected. If the surface of the object reflecting the light is flat and polished, such as a plane mirror, the light is reflected without changing the relative arrangement of the rays, as illustrated in figure 8-2.

The ray from the source to the mirror MN, is the incident ray. The point at which the ray strikes the mirror surface is the point of incidence P. The ray that comes from the point of incidence is the reflected ray. The line perpendicular to the surface of the mirror at the point of incidence is called the normal to the

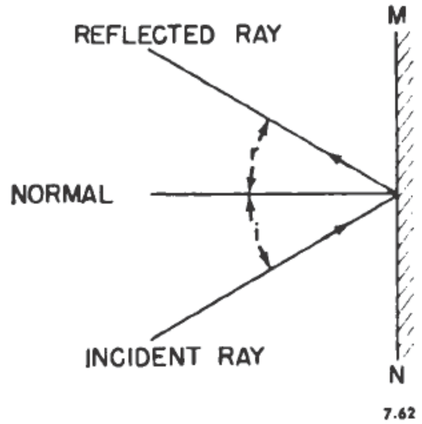


Figure 8-2.—Reflection of a light ray.

surface. The angle between the incident ray and the normal to the surface is the angle of incidence i, and the angle between the reflected ray and the normal to the surface is the angle of reflection r.

In accordance with the law of reflection, angle i equals angle r. In other words, the incident ray, the reflected ray, and the normal to the surface at the point of incidence are all in the same plane, and the angle of reflection equals the angle of incidence. This statement is true for both plane and curved mirror surfaces because the incident and reflected rays travel in the same medium with the same velocity.

Light rays reflected from a concave mirror are concentrated into a very small area and are called converging rays over the distance from the mirrot to the point of maximum concentration. Beyond the point of maximum concentration they are diverging rays.

REFRACTION

When light travels in one medium and encounters a second medium of different optical density, part of it is reflected and part continues into the second medium, as illustrated in figure 8-3. Unless the angle of incidence is zero, the light that enters the second medium undergoes a change of direction. The ray that enters the second medium is the refracted ray. The angle of refraction r is the angle between the refracted ray and the normal to the surface of the second medium. Reflection and refraction both occur at the boundary surface P between the two media. Thus the boundary serves as a plane surface for one ray and as a refracting surface for the other ray.

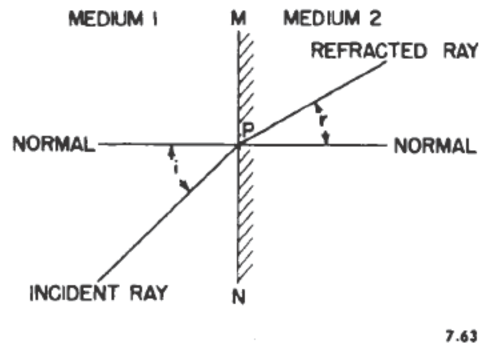


Figure 8-3.—Refraction of a light ray.

LENSES

A lens is a piece of glass or other transparent substance, the surfaces of which have been ground for the purpose of directing light rays. The refraction of light rays through various media is illustrated in figure 8-4.

If light rays pass from one medium to a denser medium having parallel faces, such as plate glass, the rays emerge from the denser medium and travel in the same direction in which they traveled prior to entering the denser medium (fig. 8-4, A). Thus, light rays are offset

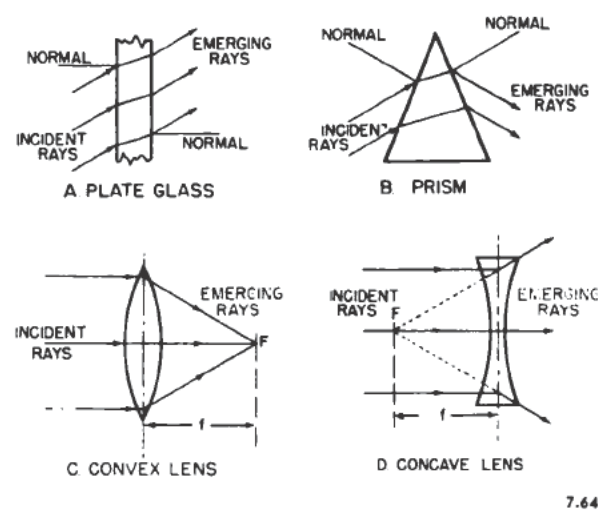


Figure 8-4.—Formation of an image by a convex lens.

slightly when passing through an ordinary window pane, but are not changed in direction.

If the faces of the denser medium are not parallel, the rays are permanently bent and emerge from the denser medium and travel in a direction different from that traveled before they entered the denser medium (fig. 8-4, B). Hence, the light rays are bent in passing through a prism with flat surfaces. If the rays are of the same wavelength and parallel, the emerging rays are also parallel.

If parallel light rays pass from one medium to a denser medium having curved surfaces, such as a lens, the emerging rays are not parallel but are concentrated, or focused, to a small point. The principal focus F of the lens is the point of convergence or of divergence of the light rays.

A double-convex and a double-concave lens are illustrated in figure 8-4, C, and D, respectively. The rays converge to point F in the convex lens and diverge from point F in the concave lens. The distance from the principal focus F to the lens is called the focal length f. Thus, it is possible to concentrate, or to control, light rays by passing them through a dense transparent substance such as glass.

FORMATION OF IMAGES

The projection of motion pictures on a screen is based on the principle of the formation of an image by a convex lens. A lens can be used to form an image of an object on a screen if all the light radiated from each point on the object and incident upon the lens can be brought to a focus at corresponding points on the screen.

If AB represents any lighted subject such as an illuminated film (fig. 8-5), some of the rays of light from A are intercepted by the lens and are brought together at point A' on the opposite side of the lens. For simplicity, only two rays are shown. One of the rays from point A in the object passes through the optical center of the lens and strikes the screen at A'. Another ray from point A parallel to the axis of the lens is refracted by the lens and also strikes the screen at point A'. Any other ray from A, incident upon the lens, also strikes the screen at point A'. Point A' is the image of point A in the object. Similarly, all the light rays from point B in the object strike the screen at point B'. Point B' is the image of point B in the object. Every other

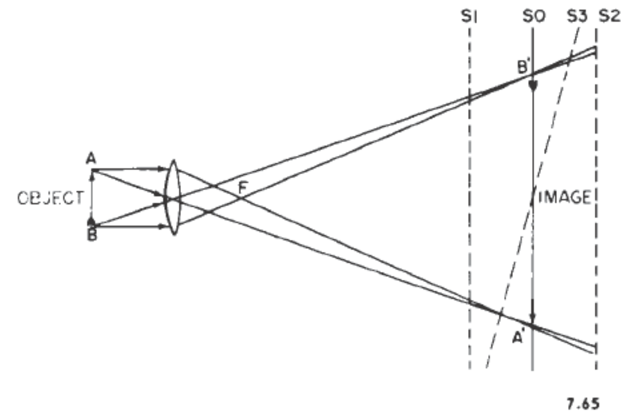


Figure 8-5.—Refraction of light rays.

point in the object is represented by a corresponding point in the image. Note that the rays cross as they pass through the lens, and the image on the screen is inverted with respect to the object. Hence, when motion pictures are projected, the images on the film must be upside down.

For a given distance between the lens and the film, there is only one screen distance at which the picture will be sharp. Light rays from a point in the film meet at a point on the screen in the plane SO. If the screen is either nearer to the projector as S1, or farther from it as S2, the rays produce a blur because they do not all strike the same point. For any screen distance there is a corresponding film-to-lens distance that will produce a sharp picture. In practice, the screen distance is usually selected to provide the desired size picture and then the lens is moved in or out until the picture is the sharpest. This adjustment, called focusing, is accomplished by rotating the projector lens barrel to move the projection lens closer to or farther away from the film. The screen should be at right angles to the lens axis. If the screen is tipped as S3, the picture will be out of focus at the top and at the bottom, although it may be sharp at the middle.

PRINCIPLES OF SOUND MOTION PICTURES

Motion picture projection is the presentation on a screen of a series of images taken in very rapid succession by a motion picture camera. Such a presentation produces an illusion of

moving images. This illusion results from viewing in very rapid succession, a series of images, each of which differs slightly from the preceding one. The eye retains an impression of the preceding image, blends it with the succeeding image, and creates an illusion of motion. In motion picture terminology an image is known as a FRAME.

SOUND MOTION PICTURE FILM

Sound motion picture film is available in standard 35 and 16 mm sizes. The 35-mm film travels through a 35-mm projector at the rate of 90 feet per minute and is the standard size for theatrical projection. The 16-mm film travels through a 16-mm projector at the rate of 36 feet per minute and is the standard size used in the Navy. The 16-mm film is a strip of cellulose acetate, one surface of which is coated with photographic emulsion. A row of perforated sprocket holes (one hole to a frame) is on one side of the film. The sprocket holes provide a positive feed for the film through the camera and projector.

A sound motion picture film (fig. 8-6) contains two types of records: (1) a series of instantaneous photographs taken in rapid succession of a moving subject; and (2) a record of sound associated with, or appropriate to, the motion of the subject.

When the series of instantaneous photographs is being recorded by the motion picture camera, the sound is picked up by a microphone that converts the audible sound waves into equivalent variations in electric current. The electric current is amplified and then photographed on film by a camera sound recorder. The recorder is equipped with a light modulator that converts the electric current from the amplifier into equivalent light variations and photographs the variations onto the film. The sound and picture are reproduced separately. The two films are then synchronized so that when they are printed together the reproduced sound corresponds at all times to the action of the picture.

The sound associated with an individual frame is not recorded on the sound track directly opposite that frame but at a point 26 frames farther ahead. This displacement of the sound track relative to the picture is necessary for proper synchronization of sound and picture, because the sound track must pass the scanning beam when the picture is at the aperture.

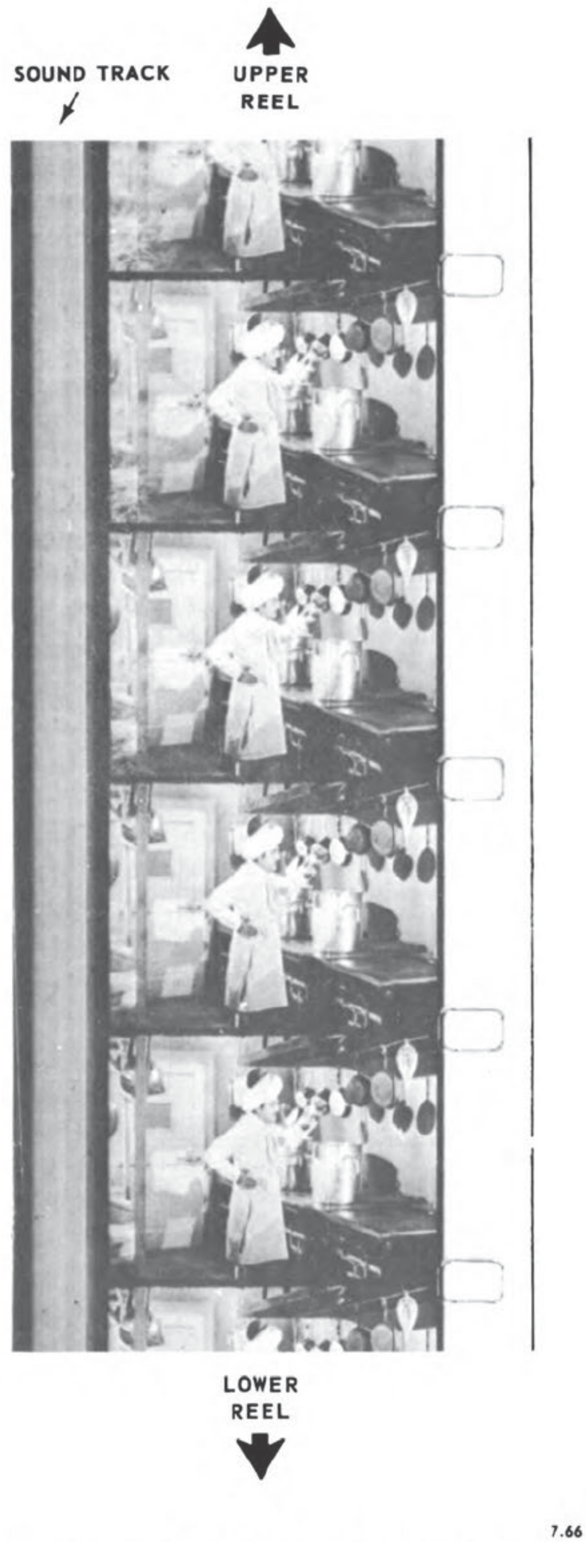


Figure 8-6.—Section of 16-mm sound motion picture film.

When such a film is shown, the photographs are projected on a screen in the order in which they were taken and at the same rate. The sound is reproduced through an amplifier and loudspeaker, and is synchronized with the action in the picture. The effect of the rapid presentation of a large number of slightly different pictures in the proper sequence gives the illusion of a continuously moving picture, and the simultaneous reproduction of the appropriate sounds augments the realism.

Sound is recorded on film as a continuous photographic image along a narrow strip at one side of the film called the sound track (fig. 8-7). The two methods of recording sound photographically on film are (1) variable area recording; and (2) variable density recording. These methods are discussed below. A third method of recording sound is the magnetic tape method (discussed in chapter 7). In this method the sound is recorded on tape and the tape is attached to the edge of the film.

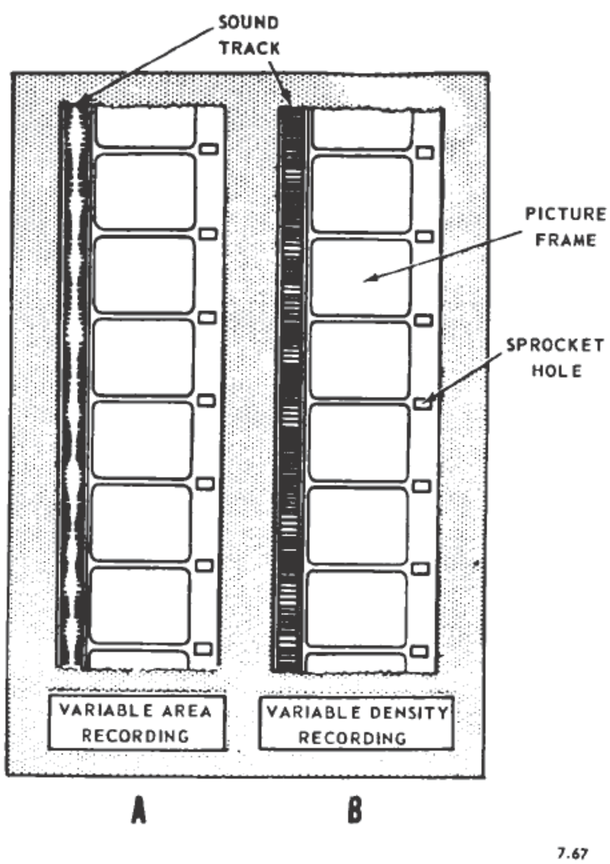


Figure 8-7.—Sound recording of film.

Variable Area Recording

Variable area recording (fig. 8-7, A) is denoted by zig-zag waves along the sound track. The black areas are opaque, and the white areas are transparent. The width of the transparent area can vary from nothing up to the limits of the opaque band, depending on the instantaneous strength of the sound being recorded. It is the variation in the width of the transparent area from point to point along the track that is of importance. When there is no variation in the width of the transparent area, no sound is recorded on the film, and no sound can be produced from it.

Variable Density Recording

Variable density recording (fig. 8-7, B) is denoted by parallel lines that vary in spacing and intensity across the sound track. If the frequency of the recorded sound is low, the width of the bands is comparatively large, and if the frequency is high, the bands of light and dark are very close together and are barely distinguishable to the eye. The variation of density between successive dark and light bands determines the amplitude of the recorded sound.

PROJECTION OF IMAGES

In sound motion picture projection each frame of the film is projected on the screen for a small fraction of a second and is immediately followed by the next frame, which is shown for an equally brief interval. A 16-mm film is projected on the screen at the rate of 24 frames every second. However, this does not imply that each frame is held on the screen for one twenty-fourth of a second. The actual time is about one half of this interval because the screen is darkened twice during each frame, once while the film is moving forward and again while a frame is being held stationary in the projector. If the light is not cut off while the film is in motion, the picture on the screen will be streaked and blurred, and if the light is not cut off at least once while each frame is stationary, an annoying flicker will result.

A sound motion picture projector consists essentially of a (1) projection optical system to project the picture on the screen; and (2) sound optical system to convert the variations in the sound track into audible sound waves (fig. 8-8).

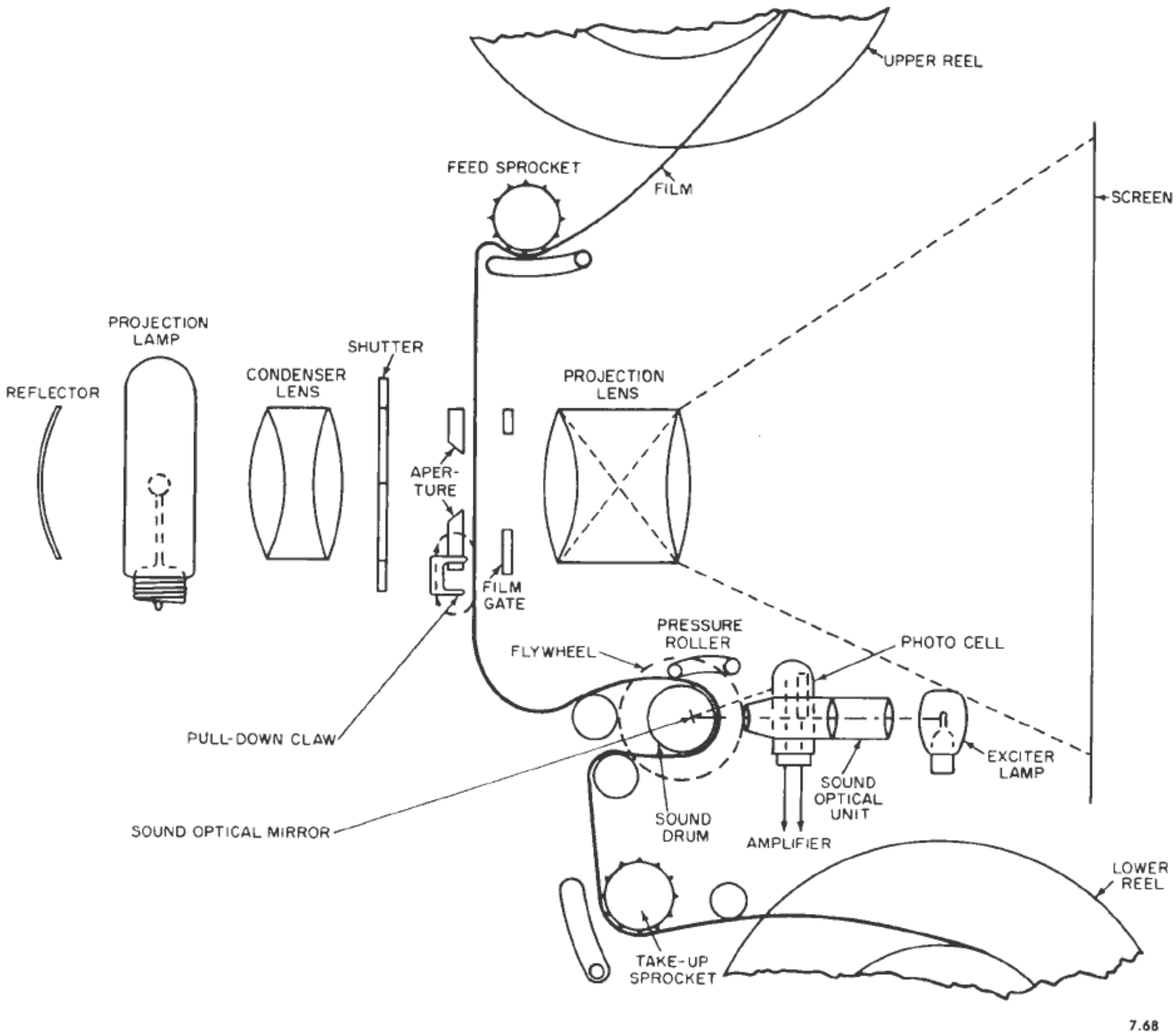


Figure 8-8.—Schematic diagram of a sound motion picture projector.

Projection Optical System

The projection optical system (fig. 8-8) includes a projection lamp, reflector, condenser lens, shutter, aperture, film gate, and projection lens.

The projection lamp is a 750- or 1,000-watt concentrated-filament lamp located behind the film. The lamp provides the light beam for projecting the film image on the screen. The reflector placed behind the projection lamp recovers much of the light emanating to the rear of the lamp and directs it forward through the optical system. The condenser lens concentrates the light from the filament of the projection lamp on the film aperture.

The shutter, placed between the condenser lens and the aperture, cuts off the light when required by a pull-down blade and an anti-flicker blade (not shown). The shutter revolves once for each frame or for each complete cycle of the intermittent shuttle (pull-down claw). The intermittent shuttle pulls the film into position in front of the aperture at the rate of 24 frames per second. Each time the intermittent shuttle moves down it advances the film one frame. During this motion, the shutter pull-down blade cuts off the light from the screen. As the

intermittent shuttle moves back up, one frame of the film is held stationary in the aperture, and the shutter antiflicker blade cuts off the light from the screen.

The aperture is a rectangular opening in a metal plate. It provides maximum brilliance in the projected picture by screening the beam of projected light from all film frames except the one positioned in front of the aperture. The film gate holds the film flat against the aperture and keeps the picture in focus.

The projection lens, located in front of the film, focuses the image of the film frame on the screen. The size of the projected image is determined by the distance of the projector from the screen and by the focal length of the projection lens.

Sound Optical System

The sound optical system (fig. 8-8) includes an exciter lamp, optical unit, photocell, and mirror.

When the sound motion picture film is run through the projector, it passes around the sound drum located in front of the sound optical unit. The optical unit concentrates the light from the exciter lamp into a line about 0.001 inch wide. This line of light is slightly longer than the width of the sound track. The optical unit is adjusted so that the line comes to a sharp focus at the emulsion side of the film so that its center coincides with the center of the sound track. The point on the sound track where this line is focused is called the SCANNING POINT. This portion of the film overhangs the back edge of the sound drum. The light that passes through the sound track falls on the light pipe prism which reflects it to the anode of the photocell.

In variable area recording the wave images on the sound track vary the amplitude of the scanning beam as it passes through the sound track. These variations in the scanning beam produce corresponding variations in the electron emission through the photocell. These variations are converted into voltage variations across a resistor and are fed to an amplifier (not shown). The output of the amplifier is converted into audible sound waves at the loudspeaker.

The greater the width of the sound waves or the greater the variation of density of the sound track bands (depending on the type of sound recording), the greater will be the variations in the amount of light that reach the photocell. The recorded sound track interposed between the light source and the photocell determines the variation in the intensity of light transmitted to the photocell and the rapidity with which the variations in light intensity occur. Thus, the variations in light intensity control the magnitude and frequency of the electric impulses to the amplifier.

SOUND MOTION PICTURE PROJECTION EQUIPMENT

The sound motion picture system, circuit MP is designed for use as an aid in training, briefing, and entertaining naval personnel. The system comprises a motion picture projector, external amplifier (fig. 8-9), and one or more external loudspeakers. The equipment is readily portable and can be operated in any average-size room, small theatre, or in shipboard hangars or topside where 115-volt single-phase power is available.

PROJECTOR

The projector consists of a sound motion picture projector, an internal amplifier, and an internal loudspeaker contained in a metal case. The operating switches and controls are located on a panel at the rear of the case. The projector permits: (1) dual operation of projectors with sound and picture changeover from one projector to another (applies to AQ-3 projector only); (2) operation of one projector with an external amplifier; and (3) operation of dual projectors with changeover using either internal or external amplifiers (applies to AQ-3 projector only).

Electrical System

The projector electrical system is illustrated by the schematic diagram in figure 8-10. The projector drive motor, ventilating motor, and projection lamp are energized from the ship's 115-volt 60-cycle power through receptacle J3 and the motor-lamp rotary switch S3. The r-f filter FLI, in series with the line to the drive motor, ventilating motor, and threading lamps minimizes the r-f noise. The threading lamp DS1, and panel lamp DS2 are energized when the threading lamp switch S2 is placed in the ON position.

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Figure 8-9.—Motion picture projector with external amplifier.

The projector drive motor B1 is a universal, series-wound governor type of motor. It operates at constant speed with changes in voltage from 100 to 130 volts. The motor speed is controlled by a centrifugal governor S6 mounted on the armature shaft. When the motor speed is low, S6 closes and shorts out R5, which increases the current in the circuit. Conversely, when the motor speed is high, S6 opens and inserts R5, which in turn reduces the speed. The capacitor C9, across R5 minimizes the r-f noise. Additional r-f suppression is provided by C7 and C8 connected between the armature and ground. The drive motor is connected to the projector through P5 and J5 to facilitate replacement of the entire motor assembly, if necessary.

The ventilating motor B2 is provided to dissipate the heat generated by the projection lamp and also cools the condenser lens, aperture, and film. The capacitors C4 and C5 are connected between the armature and ground to prevent r-f noise.

When S3 is in the MOTOR position, B2 is energized through contacts 5-6, and B1 is energized through contacts 11-12. The circuit for B1 is from pin 1 of J3, one side of FLI, pin 1 of J5-P5, the right-hand series field coil of B1, pin 2 of P5-J5, contacts 11-12 of S3, the upper blade of S5 in the OFF position, pin 6 of J5-P5, the armature of B1, pin 4 of P5-J5, the lower blade of S5 in the OFF position, pin 8 of J5-P5, R5, the left field coil of B1, pin 7 of P5-J5, the lower side of FLI, returning to pin 3 of J3. When S3 is placed in the LAMP and SOUND position, the projection lamp DS3 is energized through contacts 1-3 and 5-6 in addition to the drive motor and ventilating motor.

Normal operation of the drive motor and the ventilating motor is controlled by the motor-lamp switch S3, when the rewind switch S5 is in the OFF position. When S5 is placed in the REWIND position, terminals 11-12 in the motor-lamp switch S3 are bypassed. The drive motor operates in the reverse (rewind) direction by reversing the armature current with respect to the field. The ventilating motor and projection lamp are deenergized with S3 in the OFF position.

The exciter lamp DS4 is energized from the internal amplifier through receptacle P3, contacts 13-14 of the motor-lamp switch S3, and the closed contacts of S1.

The photocell V1 is a germanium diode, which converts the light variations impinged on its surface to variations in electrical currents. The light source for V1 is the exciter lamp DS4. The sound track on the film interposed between DS4 and V1 causes the light variations imposed on V1. The electrical currents generated by the photocell are fed to the input of the internal amplifier through receptacle P2.

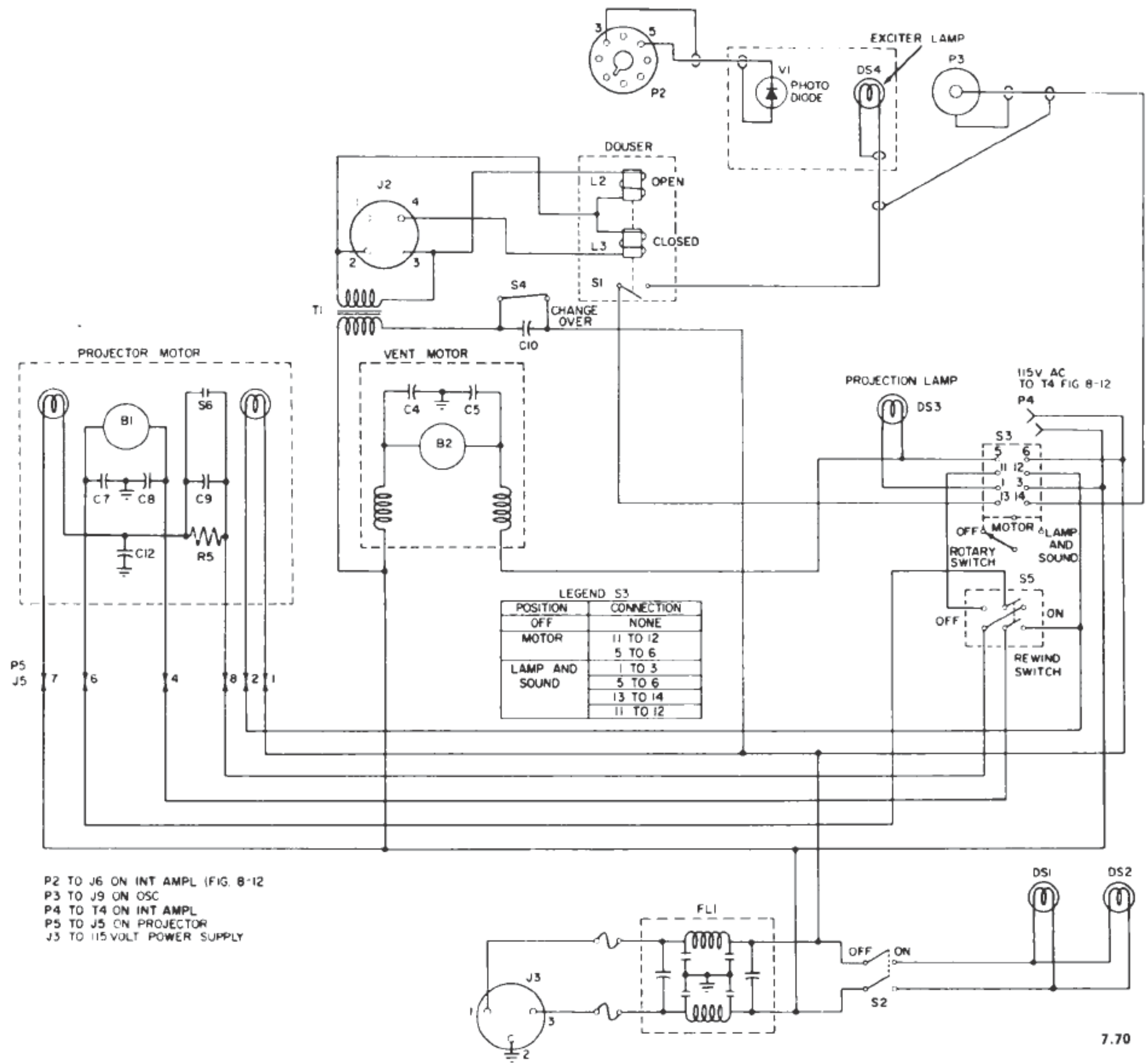


Figure 8-10.—Schematic diagram of projector.

The changeover mechanism is incorporated in each projector when two projectors are used, with one or more amplifiers and loudspeakers to provide uninterrupted sound film programs. The changeover mechanism mounts to the inner surface of the shutter assembly. Sound changeover is effected by breaking the exciter lamp circuit, and picture changeover is effected by a light shield (douser), which drops between the condenser lens assembly and the picture aperture.

The changeover switch S4 controls simultaneously the sound and picture changeover from the outgoing projector to the incoming projector. However, to effect this changeover the hand-set douser switch S1 must be preset once only, at the start of the program, to the OPEN position on the operating (outgoing) projector

and to the CLOSED position on the idle (incoming) projector. For single equipment operation, the douser switch S1 must always be set in the OPEN position.

Interconnection of the electromagnetic changeover circuits between projectors is accomplished by connecting the changeover cable into receptacles J2 on each projector (fig. 8-11). The cable connections to J2 parallel the (OPEN) solenoid of projector 1 with the (CLOSE) solenoid of projector 2. Depressing the changeover pushbutton switch S4, simultaneously energizes the (OPEN) solenoid of the desired operative projector and the (CLOSE) solenoid of the other projector. The capacitor C10 (fig. 8-10) is connected across the changeover switch S4, to eliminate the electrical noise resulting from the changeover switching operation.

Internal Amplifier

The internal amplifier (fig. 8-12), which is an integral part of the projector, delivers 7 1/2 watts with a total harmonic distortion not exceeding 2.0 percent at any frequency from 100 cycles to 7,000 cycles. The operating controls for the amplifier are located at the rear of the case adjacent to the projector controls. These controls include (1) on-off power switch S9; (2) volume control R20; and (3) tone control S8.

The amplifier consists of resistance-capacitance coupled voltage amplifier stages V2A, V2B, and V3A, phase inverter V3B to supply the push-pull grids of the output power amplifier V4 and V5, 180 degrees out-of-phase. The power supply V7 is a full-wave rectifier with pi-section filter to furnish power for all the tubes. The oscillator V6 is a conventional Hartley oscillator in the r-f power supply to produce the power for the exciter lamp.

The voltage generated by the germanium diode V1 (fig. 8-10) in the projector is developed across the load resistor R8 (fig. 8-12) and applied to the grid of V2A. The coupling capacitor C12 blocks the d-c photocell bias from the grid of V2A. The grid load resistor consists of potentiometer R42 and R10 in series with R11. The contact arm of R10, connected through R42 to the grid of V2A, permits adjustment of the input signal to prevent overloading the amplifier and to ensure a 20 db gain reserve. The degenerative feedback network between the plate of V2B and the cathode of V2A consisting of R17 in series with C17 provides increased stability and less distortion. The microphone input jack J7 allows use of the amplifier with an external high-impedance sound device such as a microphone or phonograph.

The 2-circuit 5-position rotary switch S8 is provided to control the frequency-response characteristics of the amplifier. The switch section to the left (fig. 8-12) varies the amount

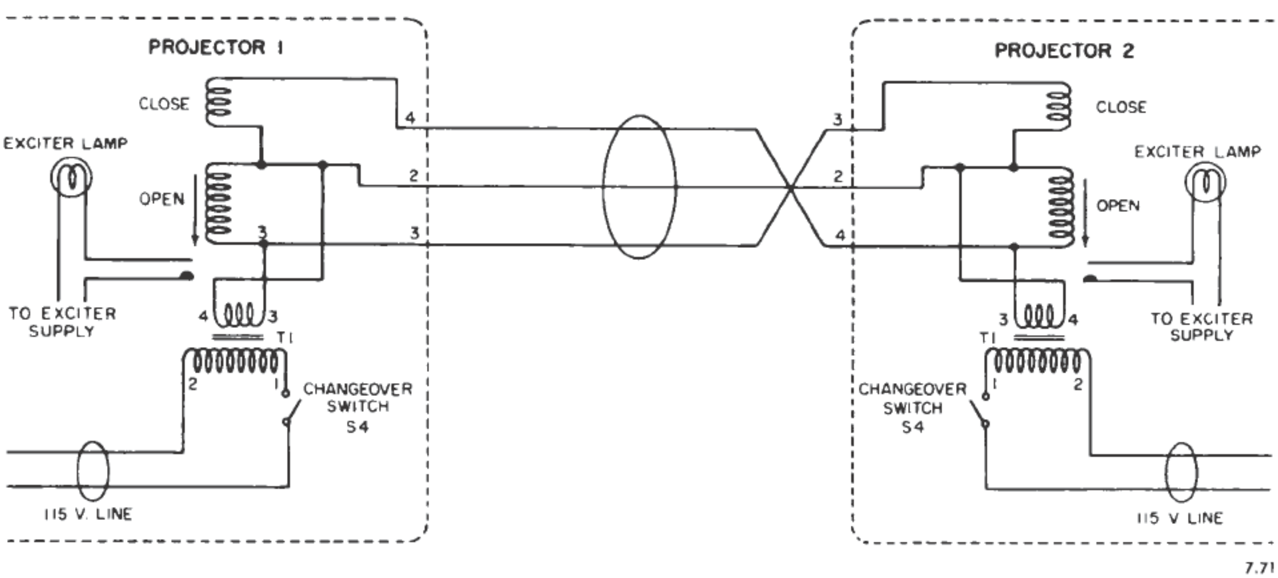


Figure 8-11.—Interconnection of electromagnetic changeover circuits between projectors.

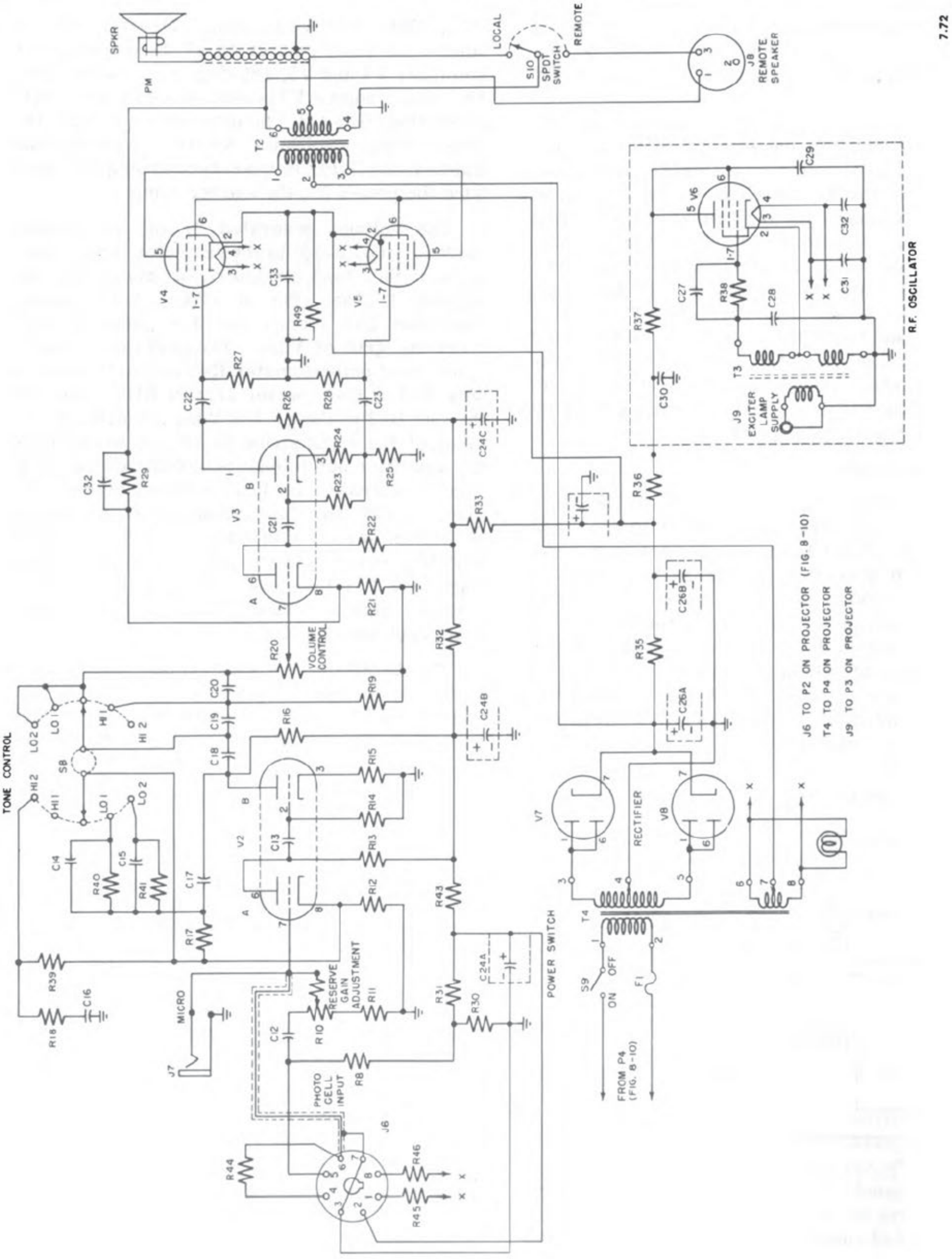


Figure 8-12. —Schematic diagram of internal amplifier.

of negative feedback applied to V2A. The feedback components are nonlinear with respect to frequency, and thus cause the gain of the stage to vary with frequency. The switch section to the right varies the frequency-response characteristics of the coupling network between V2B and V3A, and thus the signal amplitude as a function of frequency.

When the tone control switch S8 is placed in the FIRST CLOCKWISE position from normal, frequencies below 700 cps are attenuated due to the reduced coupling capacity to the grid of V3A by connecting C20 in series with C18.

When switch S8 is placed in the SECOND CLOCKWISE position, the low-frequency attenuation is increased by connecting C19 in series with C18 and C20. Also, C16 and R18 are shunted across the cathode bias resistor R12 which accentuates frequencies above 700 cps by reducing the cathode degeneration. This switch position provides 12 decibels (±2 db) of attenuation at 100 cps and 6 decibels (±2 db) of attenuation at 3,500 cps.

When switch S8 is placed in the FIRST COUNTERCLOCKWISE position from normal, C14 is connected in parallel with the feedback resistor R17 to increase the negative feedback for frequencies above 700 cps.

When switch S8 is placed in the SECOND COUNTERCLOCKWISE position, the high-frequency attenuation is increased by connecting C15 in shunt with R17. This switch position provides 10 decibels (±2 db) of attenuation at 5,000 cps. The resistors R39, R40, and R41, are provided to suppress click when switch S8 is rotated.

The signal impressed on the grid of V3A is a function of the position of the volume control potentiometer R20. Negative feedback of 10 decibels is applied to V3A through the parallel combination of R29 and C32, which is connected between terminal 6 of the output transformer T2, and the cathode of V3A. The feedback improves the stability and frequency response of the amplifier, and at the same time reduces distortion.

The phase inverter V3B drives V4 from the plate circuit, and V5 from the cathode circuit to provide the necessary 180 degree phase shift for normal push-pull operation of the power output stage, V4 and V5. The signal for V4 and V5 is developed across R26 and R25, respectively. Resistors R25 and R26 are of equal value in order to impress signals of equal amplitude on the grids of V4 and V5.

The power output stage consists of V4 and V5 connected in class AB push-pull. The output impedance is matched to the loudspeaker by the output transformer T2. The secondary of T2 is tapped to provide an 8-ohm winding (terminals 4-5) for the local loudspeaker and a 16-ohm winding (terminals 4-6) for the remote loudspeaker. Switch S10 is provided to select the desired speaker.

The Hartley oscillator V6 supplies power to the exciter lamp DS4 at a frequency of 112,000 CPS. This frequency is sufficiently high so that the thermal inertia of the lamp prevents the exciting current from modulating the output of the photocell V1. The output voltage of V6 is stepped down through the secondary of T3 to obtain the low-voltage high-current power required by the exciter lamp. The output of T3 is fed to the projector by means of a shielded cable, the outer conductor of which is grounded and connected to one side of the exciter lamp. The inner conductor is connected to terminal 14 on the motor-lamp switch S3 in the projector (fig. 8-10).

The power supply consists of transformer T4, full-wave rectifier V7 and V8, and an R-C pi-section filter (fig. 8-12). The 115-volt a-c power is obtained from the projector electrical system through connector P4 (fig. 8-10). The amplifier power switch S9 (fig. 8-12) is connected in series with one side of the line, which is connected to terminal 3 of the motor-lamp switch S3, in the projector (fig. 8-10).

Full-wave rectification is accomplished by V7 and V8. The plates of each rectifier tube are connected in parallel to safely conduct the current. The a-c components of the resulting d-c voltage are removed by the R-C pi-section filter consisting of C26A, R35, and C26B. The filter composed of R43, R31, R30, and C24A supplies the positive bias voltage for the photocell V1 in the projector.

Internal Loudspeaker

The internal loudspeaker is an integral part of the projector. It is a 5-inch 10-watt permanent magnet moving-coil type having an impedance of 8 ohms.

EXTERNAL AMPLIFIER

The external amplifier (fig. 8-13) delivers an output of 20 watts with a total harmonic

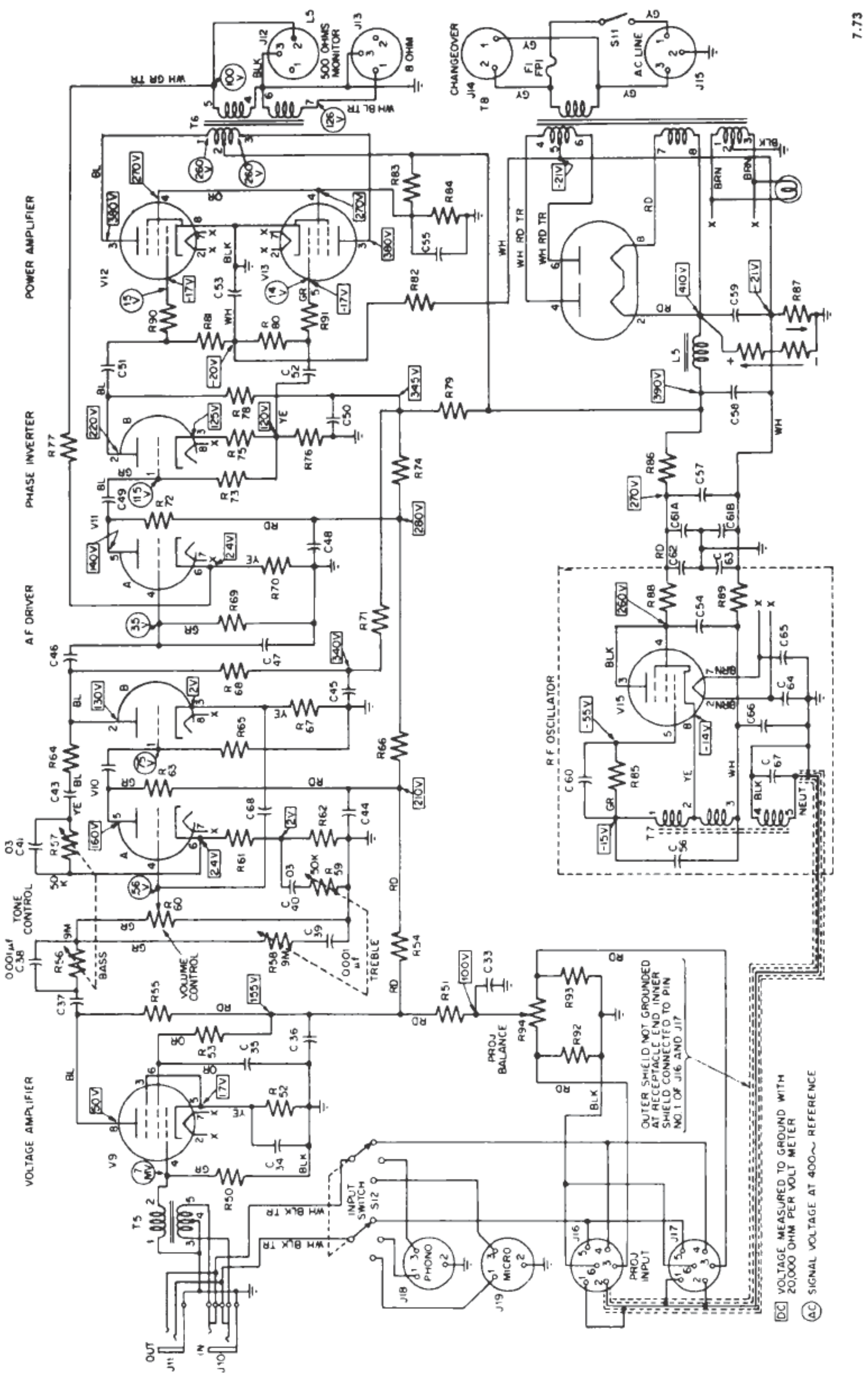


Figure 8-13.—Schematic diagram of external amplifier.

distortion not exceeding 2.0 percent at any frequency from 100 cycles to 7,000 cycles. The operating controls are located on the side of the case. These controls include (1) on-off power switch S11; (2) volume control R60; (3) bass and treble controls; and (4) microphone-phonograph-projector switch S12.

The external amplifier consists of voltage amplifier stages V9, V10A, V10B, and V11A, phase inverter V11B, push-pull power output stage V12 and V13, r-f oscillator V15 to supply the exciter lamp, and power supply V14. The amplifier is designed to function from an input signal of 0.006 volt to deliver 20 watts into the loudspeaker load with a 20 decibel reserve of amplification.

The input selector switch S12 provides for rapid switching between projectors to phonograph or microphone. The switch must always be in the PROJ. position when operating the entire equipment with 16-mm sound film.

The input circuit jack (IN), J10, and the multiple connected jack (OUT), J11, permit (1) parallel operation of two amplifiers from the input signal source; (2) use of the amplifier with any external sound device, such as microphones and phonographs, which terminate in a telephone plug; and (3) insertion of auxiliary sound equipment, such as volume compressors and volume expanders, into the input speech circuit. The insertion of a telephone plug in J11 will merely multiply the input sound circuit. The insertion of a telephone plug in J10 will disconnect the input circuit switch S12 from the amplifier input, and transfer the amplifier input to the equipment connected to the telephone plug.

The input signal is applied to the grid of V9 through the audio transformer T5. The gain of the amplifier is varied by the volume control potentiometer R60 the contact arm of which is connected to the grid of V10A. The basic feedback network between the plate of V10B and the cathode of V10A consists of R64 in series with blocking capacitor C43. A separate tone control is provided at the input of V10A to vary the high-frequency or low-frequency response of the amplifier without affecting any appreciable variation in the sensitivity between 500 cycles and 1,000 cycles.

The low-frequency attenuation network consists of C38 shunted by variable resistor R56. The high-frequency attenuation network consists of variable resistor R58 in series with C39 shunting the volume control potentiometer R60.

The low-frequency accentuation is provided by variable resistor R57 shunting C41 in series with the basic feedback network. The high-frequency accentuation is provided by C40 in series with variable resistor R59 shunting the cathode resistor R62 of V10A.

The variable resistors R56 and R57 for controlling the low-frequency response of the amplifier are ganged and operated by the BASS control, located on the operating panel. Likewise, the variable resistors R58 and R59 for controlling the high-frequency response are ganged and operated by the TREBLE control.

The output of V10 is fed to the grid of V11A, which is a voltage amplifier stage. Capacitor C46 is the coupling capacitor, and R69 is the grid load resistor. Negative feedback of 12 decibels is applied to V11A through R77, which is connected between terminal 5 of the output transformer T6 and the cathode of V11A.

The phase inverter V11B drives V12 from the plate circuit and V13 from the cathode circuit to provide the 180 degree phase shift for push-pull operation of the power output stage V12 and V13. Capacitors C51 and C52 couple V11B to the grids of V12 and V13.

The power output stage consists of V12 and V13 biased for class AB push-pull operation. A fixed negative grid bias is supplied from the rectifier V14 (across R87) through the decoupling resistor R82 terminated in the bypass capacitor C53. Grid series resistors R90 and R91 are used to suppress parasitics. The output impedance of V12 and V13 is matched to the loudspeaker by the output transformer T6, the secondaries 4-5 and 6-7 of which provide impedances of 500 ohms and 8 ohms, respectively. The output receptacle J13 is connected across the 8-ohm winding and the monitor receptacle J12 is connected across the 500-ohm winding.

The Hartley oscillator V15 in conjunction with the stepdown winding 4-5 of T7 supplies power to the exciter lamp at a frequency sufficiently high to be inaudible as modulation of the exciter lamp filament. The plate supply for V15 is supplied from the output of the rectifier V14 through dropping resistor R86. The primary 1-3 of T7 is connected across the plate and grid of V15 and is provided with a cathode tap 2. The grid bias resistor R85 in parallel with bypass capacitor C60 acts as a grid leak. The output

voltage of V15 is stepped down through the secondary 4-5 of T7 to obtain the high output current for the exciter lamp.

Capacitor C54 bypasses R-F around the power supply. The decoupling networks, R88, C62, C61A, and R89, C63, C61B are symmetrical with respect to ground. C62 and C63 are feed-through capacitors. The decoupling is such that the reactance of C62 and C61A in parallel is very much smaller than the resistance of R88, permitting negligible amounts of r-f signal to be coupled back into the d-c power supply.

Two symmetrical decoupling networks are required because the d-c power supply has a positive d-c voltage (B+), and a negative d-c voltage, and ground potential is at the junction of C62, C63, C61A, and C61B. C64 and C65 are filament bypass capacitors, and C66 is a bypass capacitor for the negative lead. The output of T7 is fed through a double shielded cable to the projector receptacle. The outer shield terminates in a button plug, which grounds at the chassis, and the inner shield terminates at pin 1 on receptacles J16 and J17.

The full-wave rectifier V14 is supplied from the secondary 4-6 of the power transformer T8. The center tap, terminal 5, is grounded through R87 to provide the negative bias for the power output stage, V12 and V13. The positive polarity filament (pin 2) of V14 is terminated in C59 and L5, both of which comprise the input of a pi-section filter. The power for the oscillator V15 is obtained at the junction of L5 and C58, feeding through R86 into C57. The filter decoupling circuit comprising R88, R89, C54, C62, C63, C61A, and C61B prevents the 112,000-cycle signal developed by V15 from feeding back into the power supply and causing r-f interference.

The voltage and decoupling resistor R51 is connected at the junction of R54 and C36, and terminated in decoupling capacitor C33, and the arm of R94. Resistors R92, R93, and R94 comprise a portion of a voltage divider between B+ and ground, the function of which is to supply the positive bias voltage for the photocells in both projectors. The projector balance resistor R94, simultaneously increases the voltage on one projector input and decreases the voltage on the other projector, and thus provides a means of equalizing the audio signal levels from two projectors. Hence, a voltage varying between 50 and 100 volts can be applied to either projector photocell circuit to provide the necessary change in a-c output from the projectors to adequately equalize the volume level. Adaptors for establishing connections between P2 (fig. 8-10), J-16, and J17 (fig. 8-13) are required (not shown in the figures).

EXTERNAL LOUDSPEAKER

The external loudspeaker is a 25-watt permanent-magnet moving coil loudspeaker contained in a metal case. The unit is equipped with a 75-foot 2-conductor cable, one end of which is permanently connected to the terminals of the loudspeaker, and the other end terminates in a 3-pin male conductor, which plugs into the output receptacle on the amplifier. A receptacle is wired in parallel with the loudspeaker circuit to permit use of a second loudspeaker with the same amplifier.

INSTALLATION

The enjoyment of any film may be dulled by careless or faulty presentation irrespective of the fine quality of the picture and the sound. Most of the success of film programs depends on the preparation prior to the showing. The vital factors involved include the proper selection and placement of the screen, seating arrangement, placement of projection equipment, selection of correct lens, and previewing of the film to be shown.

The efficient use of any screen involves projection that utilizes the entire screen surface. Motion pictures require oblong screens because of the shape of the film image. The types of screens generally used for motion picture projection have white matte or glass beaded screen surfaces. The beaded screens are not recommended for shipboard use because the glass beads fall off in salty atmosphere. The white matte screen is characterized by a wide angle of reflections, affording a more uniform brightness to the entire audience.

The angles of observation are measured from the projection axis, which is a line running from the lens of the projector perpendicular to the center of the screen surface. The best reflection and truest observation of the picture is achieved when the observer views the screen from an angle close to the projection axis. However, all observers cannot be seated close to the

projection axis, and it is essential that some latitude of observation angle be provided by screen construction. The preferred angles of observation for the matte screen are approximately 30 degrees on either side of the projection axis (fig. 8-14). To conform with this arrangement, no one should sit outside an angle of 30 degrees from the center line, not closer to the screen than two screen widths, and not farther from the screen than six screen widths.

The screen should always be placed at right angles to the lens axis and at a convenient height for viewing, with the projector placed high enough to permit the beam of light to pass well above the heads of those sitting in front of the projector. The screen height should be such that the lower edge is at least as high as the heads of those sitting nearest to it. If two projectors are used, the screen should be perpendicular to a line drawn midway between the two projectors and the center point of the screen should be on this line.

The focal length of the lens used in the projector is closely related to the screen because the lens determines the size of the screen image. The 16-mm projector is usually

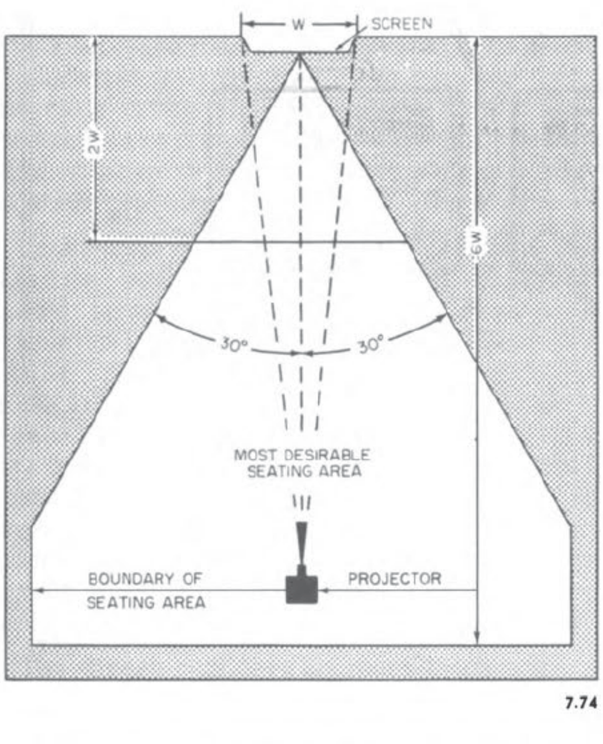


Figure 8-14.—Seating diagram for matte screen.

supplied with a lens having a focal length of 2 inches, which meets average projection conditions. However, when it is necessary to depart considerably from average conditions, the focal length of the lens can be readily determined from the equation,

$$F = \frac{3}{8} \times \frac{d}{w}$$

where F is the focal length in inches, 3/8 is a constant, d the distance between the lens and screen in feet, and w the width of the screen in feet. For example, if the focal length of a lens for use in a small room where the distance between the lens and screen is 24 feet, and the width of the screen is 6 feet then

$$F = \frac{3}{8} \times \frac{24}{6} = 1\ 1/2 \text{ inches}$$

If a lens of the computed focal length is not available, use a lens having the nearest focal length. This computation does not apply for Cinemascope pictures.

Place the projector at least 6 feet behind the last row of seats to eliminate any disturbing influence of the projector and its normal operating noise. Be certain to locate the projector at a sufficient distance from the screen so that the projected pictures will not overrun the screen. The closer the projector is to the screen, the smaller the image. Conversely, the farther the projector is from the screen, the larger the image.

The location and choice of loud speakers to ensure adequate sound intensity in various parts of the sound area requires special considerations. These considerations will vary considerably, depending on whether the projection equipment is installed in a hangar deck or topside. If it is installed in a hangar deck, the problem of echoes and reverberations is introduced, and if it is installed topside, the problem of high-level distraction noises generated by the ship and by the wind passing through and around the superstructure must be considered.

Topside

The topside installation of projection equipment requires special consideration of the location and choice of the loudspeakers because the physical construction of the designated assembly area aboard ship is not designed for entertainment. Therefore, a combination of directional horn loudspeakers and direct

radiators is required to cover the audience area with a uniform intensity level of sound.

The direct radiator loudspeaker has a relatively wide angle of sound distribution and is particularly fitted for use in the proximity of the screen. A direct radiator can be expected to cover a distance of 75 to 100 feet, depending on the amount of distracting noise generated by the ship. The horn loudspeaker, on the other hand, has a relatively narrow angle of sound distribution and is well suited to cover areas 75 feet or more away from the screen. The horn loudspeaker should be mounted on the top of the screen frame and directed so that the focal point of the sound output converges at approximately 125 feet from the screen.

The recommended loudspeaker combination, therefore, comprises two direct radiators and two horn loudspeakers. The direct radiators are mounted on the screen frame (one on each side) and tilted to cover the front half of the audience, and the horn loudspeakers are mounted on top of the screen frame (one on each side) and tilted to cover the rear third of the audience. In order to secure uniformity of the sound level over the sound area, each of the two banks of loudspeakers can be adjusted independently of the other.

Dual projection equipments utilizing external amplifiers (fig. 8-15), are required to secure the previously discussed uniform sound distribution and to assure a professional presentation. The amplifiers are designated as the

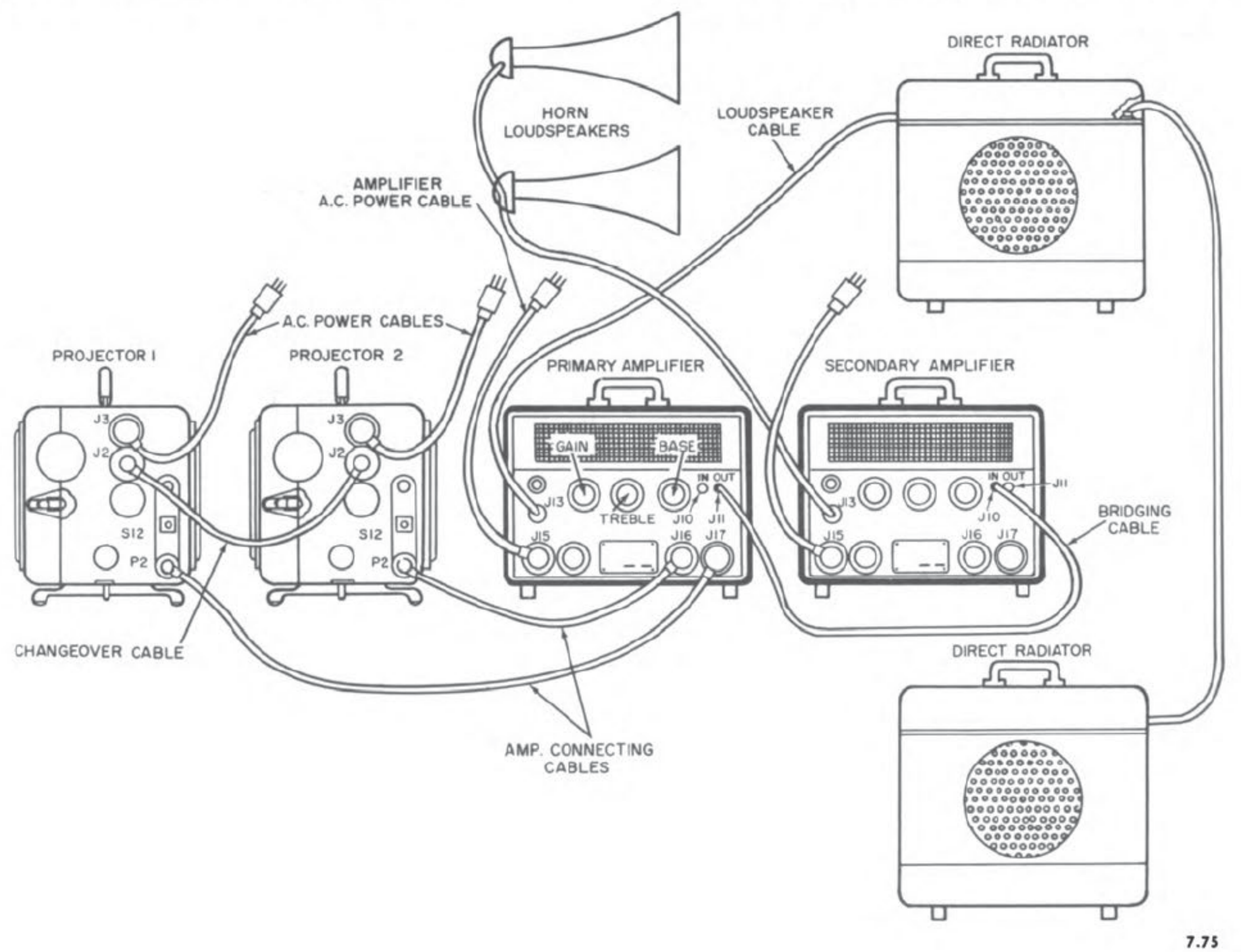


Figure 8-15.—Interconnection of dual projection equipments.

PRIMARY amplifier and the SECONDARY amplifier. All input connections are made to the primary amplifier, the output of which is fed to the monitor speaker (not shown) and the direct radiator bank.

The secondary amplifier input signal circuit is connected to the sound input circuit of the primary amplifier by a bridging cable. The interconnection is between the OUT bridging jack J11 of the primary amplifier and the IN bridging jack J10 of the secondary amplifier. This arrangement disconnects all of the input receptacles on the secondary amplifier, making it a slave to the input circuits of the primary amplifier. The output of the secondary amplifier is connected to the bank of horn loudspeakers.

The direct radiators and horn loudspeakers have a nominal impedance of 16 ohms. When connected in parallel, the joint impedance of the two direct radiators is 8 ohms, which is a matching impedance for the primary amplifier. A similar condition exists for the two horn loudspeakers and the secondary amplifier.

The correct phasing of the loudspeakers is absolutely essential, otherwise, dead spots and loss of sound intensity will result. The loudspeakers are all mounted in the same plane at the screen, and thus all of the voice coils must be connected so that they move back and forth identically in the air gaps. If the loudspeaker voice coils are not paralleled correctly, cancellation of the loudspeaker sound output will occur, and distortion with loss of sound will result.

Loudspeaker voice coils are identified by markings, and it is essential that similarly marked terminals be tied together when connecting the loudspeakers in parallel. Check the phasing of the coils in actual operation by temporarily setting the loudspeakers adjacent to each other, then reproduce a sound film as a test, and listen to the sound from the loudspeakers at a distance of 25 feet or more. A temporary reversal of the connections to either loudspeaker will furnish a quick answer as to the correct phasing of the units. Loss of level, when incorrectly phased, will be very evident.

The direct radiators and horn loudspeakers must be checked separately before combining them into the final array. When the loudspeakers have been correctly phased, perform the following preliminary adjustments to establish the optimum amplifier volume and tone control settings.

Turn the gain control to zero on the secondary amplifier that feeds the horn loudspeakers. Raise the gain control to position FOUR on the primary amplifier that feeds the direct radiators. Reproduce a sound film and note the gain control setting necessary to furnish adequate volume at a distance of 50 feet from the screen. Energize the horn loudspeakers and establish the gain control setting to secure the same volume level at a distance of 125 feet from the screen.

The horn loudspeakers will not reproduce frequencies effectively below 200 cycles, and to avoid reverberations the bass control on the secondary amplifier should be set at the ATTEN position. The treble control should be set at the NORMAL position for most films. The tone controls on the primary amplifier that feeds the direct radiators should be set at NORMAL, or varied according to the film correction required.

This topside amplifier-loudspeaker combination will provide satisfactory sound coverage over areas 75 feet by 200 feet with a reserve of power still available.

Hangar Deck

The successful installation of projection equipment in a hangar deck involves acoustic problems not encountered in the comparatively simple case of sound transmission in open air. The bulkheads, overhead, and deck of an enclosed area partly reflect and partly absorb sound originating in the enclosure, and introduce echoes and reverberations that may seriously impair the quality or character of the sound.

When a surface of a room is situated so that a reflection from it is outstanding and is heard by a person an appreciable length of time later than the direct sound, it will appear as a distinct echo and will be disturbing. If the surface is concave, it may have a focusing effect and concentrate reflected sound energy at one locality. Such a reflection may be several decibels higher in level than the direct sound, and its arrival at a later time will be particularly disturbing. In this case the offending surface can be covered with absorbing material to reduce the intensity of the reflected sound; the surface can be changed in contour to send the reflected sound in another direction; or some improvement may be obtained by changing the loudspeaker

to a new position. However, the best method of solving any particular problem will depend on local conditions.

The most common acoustic defect encountered in a large room is that of excessive reverberation. Reverberation is the persistence of sound due to the multiple reflection of sound waves between the several bulkheads of the room. Some of the sound from the distant sources overlaps the succeeding sound and remains in the room as audible delayed images of the original source. The longer the time interval between reflections, and the lower absorbing efficiency of the reflecting surfaces, the longer will be the time that this residual sound will persist. The result is an overlapping of the original sound and its images. This reverberation, if excessive, causes a general confusion which is detrimental to speech intelligibility.

If a single loudspeaker is mounted in a large reverberant area, such as a hangar deck, the intelligibility directly in front of the loudspeaker would be satisfactory. As the distance from the loudspeaker or the angle of the loudspeaker sound axis is increased, the intelligibility decreases rapidly. This condition is based on the fact that the sound from a loudspeaker in a reverberant space may be considered as composed of (1) direct sound which reaches the listener directly without having suffered any reflection; and (2) indirect sound which has suffered at least one reflection.

Indirect sound builds up because each of the multiple rays of sound energy leaving the loudspeaker strike some point on the surface of the room and are then reflected again and again until the energy is completely absorbed. Each point of reflection may be considered as a new source of sound. A large number of these image sources will be established so that sound distribution in a room tends to remain substantially uniform. The direct sound intensity, on the other hand, decreases inversely as the square of the distance from the source, as it would in open air. Intelligibility under these conditions is related to the ratio of direct to indirect sound, so that as a person moves away from the loudspeaker, the ratio of direct to indirect sound at the listening position decreases and the intelligibility decreases correspondingly. The conclusion is that in a highly reverberant space the intelligibility decreases with distance from the loudspeaker.

The present practice employed in aircraft hangar decks is to mount a number of loudspeakers at frequent intervals on the overhead, facing directly downward. This arrangement decreases the distance from any listening point to the nearest loudspeaker and increases the ratio of direct to indirect sound.

There is a time delay associated with the transmission of sound over any appreciable distance attributable to the finite time required for sound to travel through air. By locating the loudspeakers through the hangar area, a portion of the sound from the distant loudspeakers will be heard along with local loudspeakers, but will be retarded in time phase. The average duration of a single syllable of speech is about 0.2 second. It is obvious then, that one syllable from the distant sources overlaps the succeeding syllable from the nearest source, with resulting confusion and poor intelligibility. This overlapping can be reduced by loudspeaker locations (on the overhead directed downward), which do not favor transmission of sound along the length of the hangar space.

Some sound energy is absorbed at each reflection. If the number of reflections per second is increased, more sound is absorbed per unit time, the reverberant sound dies away faster, and more attenuation occurs along the length of the hangar deck. Because the vertical dimensions of hangar areas are the smallest, and because the loudspeaker sound output characteristic is essentially directional, more reflections will occur per unit time for sound traveling up and down than any other primary mode of sound travel, with a consequent greater sound absorption. This condition also favors the overhead location of the loudspeakers.

Individual switching of the speakers allows disconnection of those not covering the audience. This action reduces needless reverberations and echoes and greatly increases intelligibility.

The most obvious improvement that could be made in hangar decks would be to reduce the reverberations by the use of sound-absorbing materials. The most practical location for such material would be on the overhead where the absorption would be most effective for the vertical mode of sound travel established by overhead loudspeaker mountings. In all new construction carriers beginning with CVA-59,

this acoustical treatment for hanger decks has been incorporated.

Excessive volume in the enclosure provided by the hangar deck area will result in a marked increase in reverberations or echoes. The correct VOLUME LEVEL is that which provides adequate loudness without excessive reverberation. It is important to remember that the intelligibility of the program suffers decidedly at the very slightest overload of the amplifier. However, the 20 watts of power provided by the overhead type of loudspeaker supplied to carriers is adequate for the largest carrier. A power reserve of 20 watts may be obtained by parallel operation of the external amplifiers.

The TONE CONTROL setting is best which results in the highest degree of intelligibility. In general, it is best to attenuate the low frequencies because reverberation is now pronounced at the low frequencies, which do not contribute to the intelligibility. Therefore, the control (BASS) should be set in the maximum attenuate position. Conversely, the TREBLE control should be set in the maximum accentuate position depending on the condition of the film with respect to film noise.

The noise level aboard a carrier is of such a high amplitude and character that compression of the sound is essential in order to make low sound level sequences intelligible. In other words, the operator must constantly control the volume, otherwise, low level sound will not be heard, or high level sound will overload the amplifier.

OPERATION

Only qualified personnel are authorized to maintain and operate motion picture projection equipment. To connect the projection equipment for single equipment operation, turn the motor-lamp switch S3 (fig. 8-10), and the external amplifier on-off switch S11 (fig. 8-13), to the OFF position. Turn the gain control (fig. 8-15) and the tone control on the external amplifier to the NORMAL position. After determining that the equipment is properly grounded plug the a-c power cable from receptacle J3 on the projector into the ship's 115-volt 60-cycle power supply. Place the loudspeaker selector switch S12 on the projector in the LOCAL or REMOTE position, depending on whether the internal loudspeaker or an external, 16-ohm loudspeaker is to be used. Be certain that the douser switch S1 (fig. 8-10), is in the OPEN position, the rewind switch S5 is in the OFF position, and the rewind knob on the feed reel arm (not shown) is in the OUT position and properly engaged in the short slot.

To operate single projector equipment, turn the motor-lamp switch S3 to the MOTOR position. When showing training films, as soon as the end of the film leader passes the picture aperture, turn S3 to the LAMP position, and at the same time, increase the amplifier volume control to the required setting for proper sound volume. When showing 16-mm entertainment films, numbers starting at 12 and ending at 3 (at regular intervals) are on the film following the end of the film leader. When the last number passes the picture aperture, turn S3 to the LAMP position.

To operate dual projector equipment (fig. 8-15), place projector 1 in operation as explained for a single projector. While the film is running through (outgoing) projector 1, mount the second reel of film to the feed reel arm, and an empty reel to the takeup arm of (incoming) projector 2. Thread projector 2 and set the douser switch S1 in the CLOSED position (fig. 8-10). As projector 1 nears the end of the reel, watch for the opaque dot which appears for an instant in the upper right-hand corner of the screen. When the dot appears, turn S3 on (incoming) projector 2 to the LAMP position. Another opaque dot will appear in the same position on the screen approximately 6 seconds after the first one. When this dot appears, depress the changeover pushbutton S4 on (incoming) projector 2 and turn off (outgoing) projector 1 by placing S3 in the OFF position. The changeover button S4 when depressed on projector 2, opens the douser S1 of (incoming) projector 2 and the picture is projected on the screen accompanied by sound. The picture and the sound are cut out from (outgoing) projector 1.

To stop the projector equipment, place S3 in the MOTOR position and turn the volume control to the extreme counterclockwise position as soon as the sound or end title on the end of the reel has faded out. Allow the remaining film to run through the projector and then turn S3 to the OFF position.

MAINTENANCE

The corrective maintenance of sound motion picture projection equipment is divided into the categories of emergency repair service, which is performed aboard ship or in the field, and major overhaul and repair which is performed by a repair ship or shore activity. Only emergency repairs which are accomplished aboard ship or in the field are discussed here.

Projector

The projector equipment is setup for sound operation with the sound film properly threaded in the projector, the on-off amplifier toggle switch in the ON position, the loudspeaker selector switch in the LOCAL position (if external speaker is not used), the volume control in the MID position, and the motor-lamp switch in the LAMP position.

If no sound is present under these conditions, check the projector sound system consisting of the exciter lamp, photocell, and associated light path elements (fig. 8-10). The motor-lamp switch, when placed in the LAMP position, should light the exciter lamp. If the lamp does not operate, replace it with one that is known to be good. If the new lamp does not operate, replace the exciter lamp oscillator tube V6 in the internal amplifier (fig. 8-12).

If sound is not present after replacing the oscillator V6 insert a piece of cardboard or heavy paper between the sound drum and sound lens (fig. 8-8) to obstruct the optical light path with no film in the projector and with the volume control at the MID position. This action should produce a "plop" in the speaker. If no "plop" is heard, it may be the result of a bad photocell, an open or shorted photocell cable, misalignment of the light path, or an obstruction such as oil, dirt, or a piece of broken film. Do not attempt to remove or adjust the lens of the sound optical system because this requires special training and equipment. If sound is obtained after the foregoing checks, the trouble is in the internal amplifier or loudspeaker.

Internal Amplifier

If the amplifier pilot lamp (fig. 8-12) does not operate, the lamp is defective or no filament power is present. If the tubes do not heat after allowing approximately 1 minute to warm up, no a-c power is being delivered to the amplifier. Check the fuse and replace if necessary. If the pilot lamp and tube filaments are operating normally but no sound is forthcoming, move the output tube V5 in and out of the socket with no film in the projector, with the motor-lamp switch in the MOTOR position, and with the volume control in the extreme clockwise position. If noise is heard from the loudspeaker as the tube pins make and break contact with the socket, it indicates that the output tube V5 and the loudspeaker are operating. Repeat this test with the output tube V4. Noise from the loudspeaker indicates that V4 is good.

If no noise is heard when either V4 or V5 is moved, check the loudspeaker connections and speaker selector switch. If the connections are intact and the selector switch is in the proper position, replace the rectifier tubes V7 and V8 (fig. 8-12).

If noise was heard when checking the output tubes V4 and V5 move the driver tube V3 in and out of the socket. A similar noise of greater intensity should be heard. Failure to produce noise at this point indicates a bad driver tube V3. Repeat the same procedure for the input tube V2.

The performance of the internal amplifier, with respect to the audio signal, cannot be determined without a steady amplitude input signal. A 400-cycle test film can be used to supply the audio frequency signal for all amplifier emergency audio frequency measurements. If desired, the film can be used in the form of a loop about 3 feet in length.

The a-c signal voltages must be measured with a high-impedance vacuum-tube voltmeter, otherwise the readings will be in error. The amplifier should be terminated in a 16-ohm load resistor instead of the external loudspeaker, when taking output power measurements. The a-c signal voltages are indicated by the voltage enclosed in a circle with an arrow pointing to the exact point of measurement (fig. 8-12).

The d-c voltages for normal conditions are designated by the voltage valve enclosed in a rectangular block with adjoining arrow to indicate the point of voltage measurement (fig. 8-12). A 20,000 ohm-per-volt type of meter must be used for taking the d-c measurements.

Internal Loudspeaker

The internal loudspeaker is an integral part of the 16-mm projector. It is a 5-inch dynamic loudspeaker containing a permanent magnet and moving voice coil. To gain access to the loudspeaker, remove the speaker mounting panel from the projector case and place it on a bench. Check the loudspeaker cone for holes or cracks. Apply equal pressure to all sides of the cone and gently push the cone with the fingers to be certain that the voice coil is not rubbing in the air gap. Be careful not to damage the loudspeaker when making this inspection. Unsolder the connection from the terminals of the loudspeaker and check the d-c resistance of the voice coil with an ohmmeter. The d-c resistance should be approximately 8 ohms.

The procedures used to localize troubles and effect emergency repairs to the internal amplifier and loudspeaker are also followed when performing similar maintenance on the external amplifier and loudspeaker. The scope of this training course does not permit a complete coverage of the operation, care, and maintenance of the sound motion picture projection equipment. More detailed information is contained in chapter 85 of the *Bureau of Ships Technical Manual* and the manufacturer's instruction book furnished with the equipment in use aboard your ship.

A recent experimental modification to the 16-mm motion picture projector permits the use of a Xenon arc-lamp light source instead of the incandescent type of lamp. Although additional components are used including the power supply and controls required to operate the lamp and portions of the projector have been extensively modified, the operation and construction are essentially the same as that for the equipment utilizing an incandescent lamp. This type projector is still undergoing tests and is not standard equipment.

QUIZ

1. Name two natural sources of direct radiation.
2. Name two natural sources of indirect radiation by reflection.
3. Why does the incandescent electric lamp produce light?
4. Are light waves transverse or longitudinal?
5. What is indicated by the height of the crest or the depth of the trough of a light wave?
6. What is indicated by the distance between successive points in identical stages of motion of a light wave (fig. 8-1)?
7. What is indicated by a line connecting particles of the medium over which the disturbance is momentarily uniform (fig. 8-1)?
8. What is represented by a line drawn in the direction of propagation from a light source (fig. 8-1)?
9. What is the relation between the velocity of light, the frequency of the wave, and the wavelength?
10. What determines the sensation of color on the optic nerve?
11. Why do colored objects look natural in sunlight?
12. Can light waves be reflected and refracted?
13. What is the ray from the source to the reflecting surface or mirror called (fig. 8-2)?
14. What is the name of the point at which the incident ray strikes a reflecting surface (fig. 8-2)?
15. What is the name of the ray that comes from the reflecting surface at the point of incidence (fig. 8-2)?
16. What is the name of the line perpendicular to a reflecting surface at the point of incidence?
17. What is the angle called between the incident ray and the normal to the surface (fig. 8-2)?
18. What is the angle called between the reflected ray and the normal to the surface (fig. 8-2)?
19. What is the relation between the angle of incidence and the angle of reflection in accordance with the law of reflection?
20. What is the name of the ray that enters the second medium when light travels in one medium and encounters a second medium of different optical density?

21. What is the name of the point of convergence or of divergence of light rays passing through a lens (fig. 8-4)?
22. What is the name of the distance from the principal focus to the lens?
23. What is meant by motion picture projection?
24. What is the standard film size used in the Navy?
25. Name the two types of records contained on a sound motion picture film.
26. Why is a displacement of the sound track relative to the picture necessary for proper synchronization of sound and picture?
27. How is sound recorded on film?
28. Name the three methods of recording sound on film.
29. How is variable area recording denoted (fig. 8-6)?
30. How is variable density recording denoted (fig. 8-6)?
31. What type of lens is used in motion picture projection systems?
32. (a) How many times is the screen darkened during each frame and (b) when?
33. Name the seven components that comprise the projection optical system (fig. 8-8).
34. What is the purpose of the condenser lens in the projection optical system?
35. What is the purpose of the shutter placed between the condenser lens and the aperture in the projection optical system (fig. 8-8)?
36. What is the purpose of the projection lens located in front of the film in the projection optical system (fig. 8-8)?
37. Name the four principal components that comprise the sound optical system (fig. 8-8).
38. What is the purpose of the optical unit in the sound optical system?
39. What is the purpose of the sound optical mirror in the sound optical system (fig. 8-8)?
40. What action results from the variations in the amplitude of the scanning beam as it passes through the wave images on the sound track?
41. How are the variations in electron mission through the photocell utilized?
42. Name the three components that are integral with the sound motion picture projector.
43. What is the purpose of the r-f filter FLI in series with the line to the drive motor, ventilating motor, and threading lamps in the projector electrical system (fig. 8-10)?
44. Name the two simultaneous functions of the changeover switch S4 with respect to the outgoing projector and the incoming projector (fig. 8-10).
45. In what position is the douser switch (S1) set on the (a) outgoing projector and (b) incoming projector (fig. 8-10)?
46. Where is the input signal voltage generated by the diode V1 in the projector developed and applied to the input of the internal amplifier (fig. 8-12)?
47. What is the purpose of the coupling capacitor C12 in the grid circuit of V2A (fig. 8-12)?
48. What is the purpose of the contact arm of R10 connected to the grid of V2A (fig. 8-12)?
49. Name the components that comprise the basic feedback network between the plate of V2B and the cathode of V2A (fig. 8-12).
50. What is the purpose of the 2-circuit 5-position tone control switch S8 (fig. 8-12)?
51. What is the purpose of R29 connected between terminal 6 of T2 and the cathode of V3A (fig. 8-12)?
52. How is push-pull operation of the output stage V4 and V5 obtained (fig. 8-12)?
53. Why is the power supplied by the oscillator, V6 (fig. 8-12) to the exciter lamp in the projector at a frequency of 112,000 cps?
54. What is the purpose of the R-C pi-section filter consisting of C26A, R35, and C26B in the power supply (fig. 8-12)?
55. What is the purpose of the filter composed of R43, R31, R30, and C24A (fig. 8-12)?
56. What is the purpose of the selector switch S12 in the input circuit of the external amplifier (fig. 8-3)?
57. What is the function of the filter decoupling circuit comprising R88, R89, C54, C62, C63, C61A, and C61B between the oscillator V15 and rectifier V14 (fig. 8-13)?
58. What is the function of R51 connected at the junction of R54 and C36 and terminated in decoupling capacitor C33 and resistors R92, R93 and R94 (fig. 8-13)?
59. What means is provided for equalizing the audio signal levels from two projectors (fig. 8-13)?

60. Name the preferred seating arrangement for a matte screen with respect to the (1) projection axis, (2) minimum distance to the screen, and (3) maximum distance from the screen.
61. How far behind the last row of seats should the projector be located?
62. In a topside motion picture projection installation, (1) what is the recommended loudspeaker combination and (2) where are the types of speakers located and how directed?
63. What projection equipment is necessary to secure the uniform sound distribution from the recommended topside loudspeaker combination and to assure a professional performance?
64. How is the secondary amplifier connected to the sound input circuit of the primary amplifier (fig. 8-15)?
65. When the primary and secondary amplifiers are interconnected as indicated in question 64, what is the condition of the secondary amplifier (fig. 8-15)?
66. What condition results if the loudspeakers are not correctly phased?
67. What two acoustic problems are introduced when sound originating in an enclosure is partly reflected and partly absorbed by the bulkheads, overhead, and deck of the enclosed area?
68. What is the present practice employed when installing loudspeakers in hangar decks to decrease the distance from any listening point to the nearest loudspeaker and thus increase the ratio of direct to indirect sound?
69. If no sound is present with the projector equipment set up for sound operation, what components in the projector should be checked (fig. 8-10)?
70. What component in the internal amplifier should be replaced in the projector sound system if the exciter lamp does not operate after it has been replaced with a good one when the motor-lamp switch is placed in the LAMP position?
71. If sound is not present after replacing the component referred to in question 70, what procedure is necessary if the trouble is due to a bad photocell, open or shorted photocell cable, misalignment of the light path, or an obstruction in the light path?
72. If sound is not obtained after complying with questions 70 and 71, the trouble is in what components of the projector?
73. What two conditions are indicated if the amplifier pilot lamp does not operate?
74. If the amplifier pilot lamp and tube filaments are operating normally but no sound is available, how can the output tubes V4 and V5 and the loudspeaker be checked for operation (fig. 8-12)?
75. If no noise is heard when either V4 or V5 are checked in accordance with question 74 and the loudspeaker connection and speaker selector switch are intact, what component in the amplifier should be replaced (fig. 8-12)?

CHAPTER 9

DIAL TELEPHONE SYSTEM

The dial telephone system, circuit J, is primarily an administrative circuit that provides complete selective telephone communication throughout the ship. This system is also used to supplement other communication facilities for ship control, fire control, and damage control. The capacity of the system varies with the size and needs of the particular ship.

TELEPHONE EQUIPMENT

A telephone system consists of a group of telephones with lines so arranged at a central point that any two telephones in the system can be interconnected. In an automatic telephone system, the connections between the telephones are completed by remotely controlled switching mechanisms. In a manual telephone system, the connections between the telephones are completed by a switchboard operator.

The switching mechanisms in an automatic system are controlled at the calling telephone by a device, or dial on the telephone instrument. The dial has 10 digits, any one of which can be dialed. When the dial is operated it causes a series of interruptions, or impulses, in a current flowing in the line circuit. The number of impulses sent out by the dial corresponds to the digit dialed. These impulses cause the automatic switches to operate and to select the called telephone.

The dial telephone system (fig. 9-1) consists of: (1) telephone station equipment, (2) automatic switchboard equipment, (3) power equipment, and (4) accessory equipment.

TELEPHONE STATION EQUIPMENT

The telephone station equipment consists of various types of telephones for mounting in both protected and exposed locations. Telephones installed in locations where the noise level is so high that the telephone ringer may not be heard are provided with extension signals. An extension signal is a motor-operated horn that is controlled by a power signal relay. The power signal relay operates on ringing current to close a 115-volt ship's power circuit to the extension signal.

AUTOMATIC SWITCHBOARD EQUIPMENT

The automatic switchboard is the switching center of the dial telephone system. It includes the switching mechanisms necessary for setting up automatically the connection between any two telephones and certain miscellaneous equipment used in common by all switches.

The miscellaneous equipment includes the ringing machines, or signals, testing equipment, and control circuits for the switching mechanisms, start and stop circuits for the ringing machines, line disconnect keys, fuses, and so forth.

The switchboard proper mounts all telephone switching mechanisms, control circuits, line disconnect keys, part of the testing equipment, and most of the supervisory alarm signals. The ringing machines and the common alarm signals are usually mounted externally. The

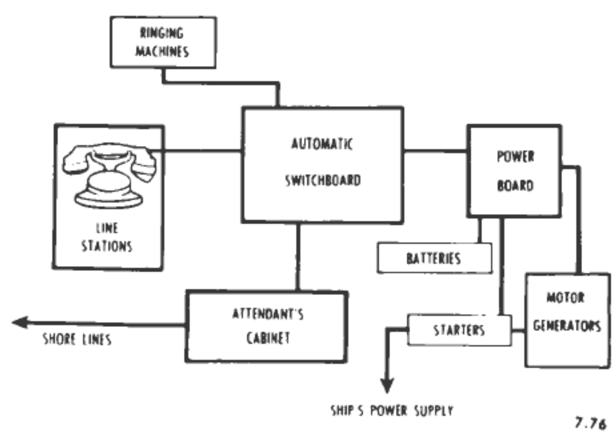


Figure 9-1.—Block diagram of dial telephone system.

switching mechanisms and miscellaneous equipment automatically locate a telephone station desiring to make a call, supply dial tone, extend the calling station to the called station in response to impulses from the dial, ring the called station, supply ringback tone or busy-tone as required, and disconnect the calling and called stations at the completion of the conversation.

POWER EQUIPMENT

The power equipment includes the power control panel, motor-generator set or rectifier, and storage battery. The motor-generator set, or rectifier, and the storage battery are connected in parallel and supply approximately 51.6-volt d-c power to operate the automatic switchboard equipment, including the ringing machines. The power to operate the motor-generator set, or rectifier is obtained from the ship's 440-volt 60-cycle 3-phase power via the nearest IC switchboard. A reserve supply of energy is maintained in the storage battery so that the telephone system will continue in operation should the ship's power supply fail.

ACCESSORY EQUIPMENT

The accessory equipment (furnished in some ships) includes an attendant's cabinet which is a small manual switchboard. The attendant's cabinet is used to establish calls to and from shore exchanges when the ship is in port, and between ships when they are nested.

A detailed description of the various equipments comprising the dial telephone system is contained in this chapter and in subsequent chapters of *I.C. Electrician 1 & C*, NavPers 10557.

PRINCIPLES OF DIAL TELEPHONE SYSTEM

Numerous methods of switching have been devised, however, the most extensively used switching equipment for shipboard installations is the Strowger automatic type. It is the type that is described here.

SWITCHING MECHANISMS

The switch mechanisms and the associated circuits are the mechanical operators that perform all of the functions required of a telephone switchboard. The major types of switches used in the shipboard dial telephone system are the linefinder, selector, and connector; all of which are Strowger switches.

The Strowger switch is an electromechanical device that extends the connection from the calling to the called telephone. It consists of a bank of electrical contacts arranged in 10 levels with 10 sets of contacts to a level. The wipers, which make contact with the selected set of contacts, are connected to the switch shaft. The switch mechanism elevates the shaft (and wipers) any number of steps from 1 to 10, and then rotates the shaft (and wipers) any number of steps from 1 to 10. When the shaft is released, it rotates backwards under the influence of a spring and then returns to normal under the pull of gravity. The Strowger switch, because of the up and around movement, is referred to as a two-motion or step-by-step switch. It is the basic switch of the step-by-step system, and with a few mechanical and electrical variations, is used as a linefinder, selector, and connector.

The LINEFINDER finds the line of the telephone station seeking to make a call and extends the line to the selector. The line-finder mechanism is controlled by the finder control relays. The impulses to step the mechanism up and around are furnished by interrupter springs on the vertical and rotary magnets. The finder switch is referred to as a NONNUMERICAL type of Strowger switch, because its operation is automatic and not under the control of dial impulses. The linefinder switch is not entire within itself like the connector, but depends on its associated line-and-cutoff relays, group control relays, and distributor relays.

The LINE-AND-CUTOFF RELAY is a relay individual to the line with which it is associated (in contrast to the switch circuits which serve many lines and the control circuits which serve many switches). For example, when a call is initiated by a telephone, the line-and-cutoff relay functions to: (1) apply ground (positive side of the battery) to start the linefinder control relays to actuate a linefinder switch to hunt for the calling line; (2) mark a contact in the bank of a linefinder by placing battery (negative voltage) on the contact so that when the linefinder wiper encounters battery the linefinder will know it has located the line it is trying to find.

The SELECTOR extends the line of the calling telephone to the connector. The vertical stepping of the selector is controlled by the first digit dialed at the calling telephone, and the rotary stepping is controlled by interrupter springs on the rotary magnet.

The CONNECTOR extends the line of the calling telephone to the line of the called telephone. The impulses transmitted from the dial of the calling telephone actuate the connector mechanism to step the wipers up and around to the set of contacts associated with the called telephone station. A connector switch is referred to as a NUMERICAL type of Strowger switch because it operates under the control of dial impulses.

More information concerning the construction and operation of the Strowger switch is contained in the training course *I.C. Electrician 1 & C*, NavPers 10557.

STATION NUMBERING

Each telephone in the 400 line system is assigned a 3-digit number. The first digit dialed causes a selector switch to step vertically. The level to which the selector is stepped determines the side of the line on which ringing current will be impressed. The arrangement of the switching facilities is such that the first digit of the telephone number for the first party on a 2-party line may be 2, 4, 6, 8, or 0. The first digit of the telephone number for the second party may be 3, 5, 7, or 9.

The second and third digits of the telephone number always correspond to the line number. If the last two digits of the telephone number are 12, for example, the set of contacts in the connector bank associated with the telephone station is the second pair on the first level in the control and line banks. Thus, when the second and third digits of the telephone are dialed, the connector switch is actuated to step the wipers up and around to the set of contacts associated with the called telephone station.

The line bank as its name implies, furnishes facilities for the line-circuit connections. One line bank furnishes facilities for 100 line connections (+ and -) and is called a 100-point bank. The 100-point line bank contains 100 sets of contacts. The control bank, as its name implies, furnishes facilities for control circuit connections (C and EC). The control bank contains 200 contacts.

The arrangement of the 100 sets of contacts that comprise the standard Strowger bank is illustrated in figure 9-2. The contacts are arranged in 10 horizontal levels with 10 sets of contacts to a level. Each set of contacts is designated by a 2-digit number which represents the number of vertical and rotary steps necessary to reach the particular set of contacts. In other words, the first digit represents the number of vertical steps and the second digit represents the number of rotary steps. Number 32, for example, is 3 steps up and 2 steps in. Note that the second digit of the called number represents the level, and the third digit represents a particular set of contacts on that level.

Numbers beginning with 1 are in the first level, numbers beginning with 2 are in the second level, and so on. This arrangement causes the digit 0 to be used to represent 10 steps so that the tenth or top level is indicated by zero and the tenth pair of contacts in each level is indicated by zero. Groups of 10 lines are referred to as lines 11-10, 21-20, 31-30, and so forth. Likewise, lines 11-50 mean a group of 50 lines. The first 10 lines consist of 11-10, and the last 10 lines consist of 51-50.

BASIC 100-LINE CONNECTOR SYSTEM

In actual practice, the switching equipment must be arranged so that any telephone in the

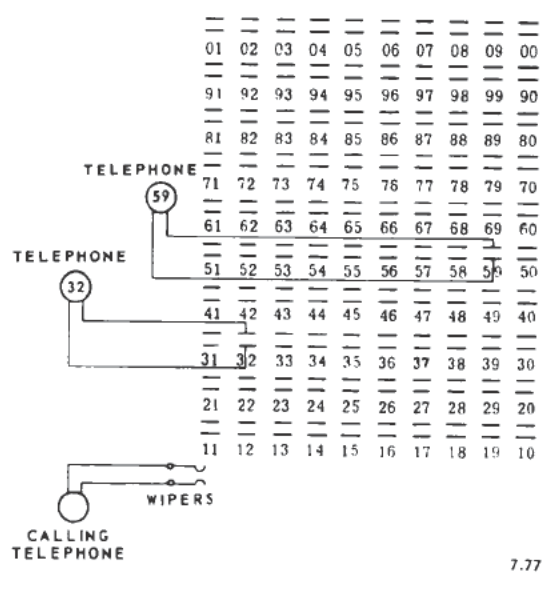


Figure 9-2.—Numbering plan of connector bank.

system can connect with any other telephone in the system. This is accomplished by arranging the switches in interconnected groups. To connect Strowger switches in groups, the banks of the switches are interconnected by connecting the respective sets of contacts in each of the banks. Switches connected in this manner are said to be multipled and the connection is usually referred to as the bank-multiple, as illustrated in figure 9-3. For simplicity, only three of the switches in this multiple are shown with an individual connector switch for each of the three telephone lines, which means that the line of each telephone is connected directly and permanently to the wipers of the connector switch assigned to that telephone. The three blocks of dots represent the banks of the three connector switches, and each dot represents a pair of contacts.

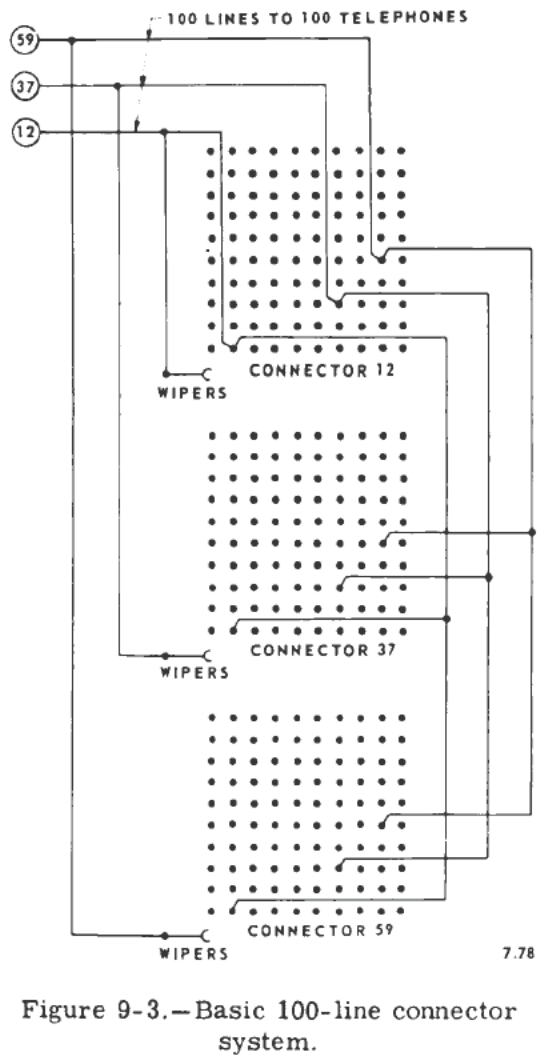


Figure 9-3.—Basic 100-line connector system.

Note that each 12 set of contacts is connected to the 12 set of contacts in each of the other banks, the 37 set of contacts is connected to the 37 set of contacts in each of the other banks, and so forth. Each of the three telephones is connected not only to the wipers of its own connector, but also to a set of contacts in the bank of each of the other connectors. Telephone 12, for example, is connected to the wipers of connector 12, and telephone 12 also has an appearance in the bank of each connector, that is—it is multipled to the 12 set of contacts in each of the connector banks. Likewise, telephone 37 is connected to the wipers of connector 37 and is also multipled to the 37 set of contacts in each of the connector banks. This multiple arrangement of the connector banks permits any telephone to call any other telephone in the system. For example, if telephone 12 calls telephone 37, telephone 12 dials the digits 3 and 7. When 3 is dialed, the wipers of connector 12 are elevated to the third level and when 7 is dialed, the wipers are rotated across to the seventh set of contacts on the third level. The connection is from this line of telephone 12 through the 37 set of contacts to the line of telephone 37.

LINEFINDING PRINCIPLE

The 100-line connector system in figure 9-3 requires an individual connector switch for each line in the system. Because the connector is a relatively expensive switch, this sytem is not economical since the average telephone is used only a short time each day and the associated connector would remain idle the remainder of the time.

The linefinding principle permits a large group of lines to be served by a smaller number of switches which are common to all lines in the group. A linefinder switch and a connector switch permanently connected to each other constitute a line finder-connector link. The linefinding principle is illustrated by the single finder-connector link, and the 100-point finder bank with the associated 100-point connector bank in figure 9-4. Note that the finder wipers and connector wipers are permanently connected to each other. The banks of the linefinder switch furnish facilities for line connections for 100 telephone stations, and therefore all lines

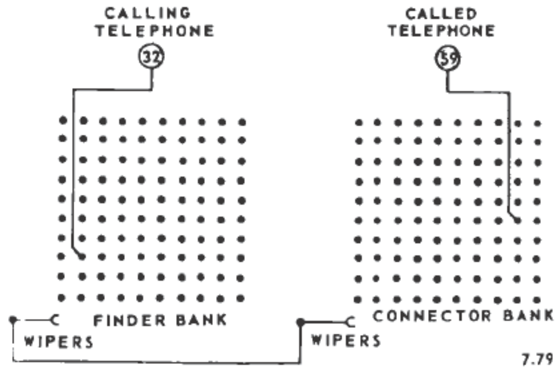


Figure 9-4.—Principle of linefinding.

are accessible to the linefinder wipers. Because the linefinder wipers are connected permanently to the wipers of the associated connector, when the linefinder finds the calling line, the calling line is thereby extended to the wipers of a connector. Thus, a connector may become associated with any line in the system.

If telephone 32 desires to call telephone 59, telephone 32 removes its handset from the cradle switch. This action closes a circuit to the line-and-cut off relay (not shown) associated with telephone 32. The relay marks the calling line in the linefinder control bank and starts the group relays (not shown) which actuate the linefinder to search for the calling line. The linefinder steps its wipers up to the third level and in to the second set of contacts, and thus telephone 32 is extended through to the wipers of the connector. When this connection is made, the connector will send dial tone to the calling telephone 32 and as digits 5 and 9 are dialed, the connector wipers will step up 5 steps and around 9 steps to complete the connection between telephones 32 and 59.

BASIC 100-LINEFINDER CONNECTOR SYSTEM

Each of the lines in the system, described with reference to figure 9-4, has an appearance in the banks of both the linefinder and the connector and thus connection is possible between any two telephones in the system. However, a telephone system with only one finder-connector link would be impractical because one finder and one connector are required to complete a connection between the calling and called telephones and therefore telephone service would be limited to one call at a time.

To make several simultaneous conversations, 25 finder-connector links are furnished for a 100-line system (fig. 9-5). For simplicity, only 3 of the 25 finder-connector links and 3 of the 100 lines in the system are shown. Note that the banks of the finders are multipled and that the banks of the connectors are also multipled. The lines 12, 37, and 59 are typical of the other lines in the system. For example, the line of telephone 12 has a point of connection in the bank of each linefinder and each connector. In other words, this line is described as having an appearance in the banks of the finders and the connectors. The conductors from the connector

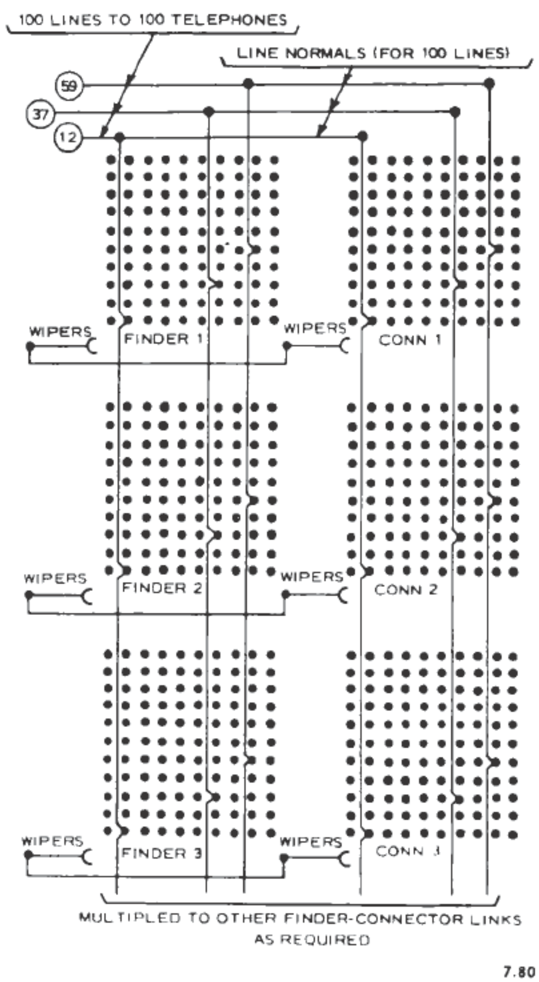


Figure 9-5.—Basic 100-line finder-connector system.

line bank to the line of telephone 12 are called LINE NORMALS.

Each pair of linefinder line wipers (fig. 9-5) is connected to a pair of connector line wipers. The wipers of the linefinder "look backward" ready to find any line desiring to make a call and the wipers of the connector "look forward" ready to connect to the dialed line. Each finder and connector that are tied together constitute a finder-connector link. Only as many simultaneous conversations can take place as there are finder-connector links because one finder-connector link is busied for the duration of the conversation.

All of the 100 lines in the system have an appearance in the linefinder multiple and also in the connector multiple. Therefore, any idle finder can step its wipers up and around to locate any one of the 100 lines that originates a call and the associated connector can step its wipers up and around, under control of dial impulses from the calling telephone, to complete a connection to any one of the 100 telephones in the system.

To call telephone 59 from telephone 37, remove the handset from the cradle switch at telephone 37. An idle finder such as finder 1, steps up 3 levels and rotates to contacts 37. The connection is now extended through to the connector associated with the finder (in this case connector 1), and dial tone is received at the calling telephone 37. When the digits 5 and 9 are dialed, the wipers of the connector switch step up to the fifth level and rotate in to contacts 59. The connection is now completed from telephone 37, through finder-connector link 1, and back over the line normals of line 59 to telephone 59. The connector switch now tests telephone 59, and if it is not in use, ringing current is sent out over the line to operate the ringer of telephone 59. If telephone 59 is found to be in use, a busy signal is returned to the calling telephone 37.

A complete 100-linefinder connector system is illustrated by the block diagram in figure 9-6. The finder and connector banks are each represented by 10 horizontal lines and the switch mechanisms are represented by the rectangles above the banks. The group of finders in the multiple is controlled by a group of control relays and a distributor (which is also a relay group). One line-and-cut-off relay is associated with each line, whereas one finder control

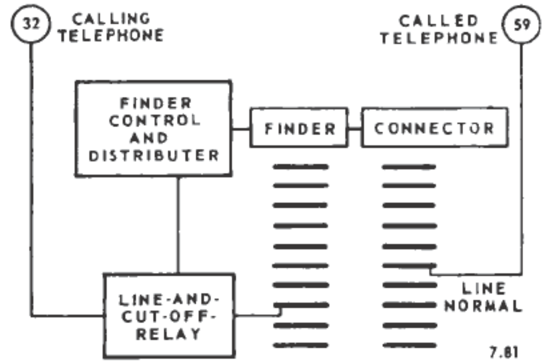


Figure 9-6.—Block diagram of complete 100-line finder-connector system.

and distributor equipment is common to all lines.

The distributor preselects the finder which is to search for the next calling line. When the line-and-cut-off relay associated with the calling line marks the calling line in the linefinder bank multiple and starts the control relays which control the finder, the finder automatically steps its wipers up and around until it finds the calling line. With the linefinder wipers resting on the set of contacts associated with the calling line, the calling line is extended to the connector wipers.

To call telephone 59 from telephone 32, remove the handset from the cradle switch at telephone 32. Line-and-cut-off relay 32 operates and marks the position of line 32 in the finder banks and also sends a START SIGNAL to the finder control and distributor equipment. The start signal causes the finder control and distributor equipment to start a preselected idle finder searching for the calling line. When the finder finds the calling line and switches through (extends the connection through to the connector switch), the control relays release to normal in preparation for actuating the next finder.

At this point line 32 is made busy at the connector banks to guard against intrusion from any incoming call. Also, the line-and-cut-off relay 32, which is a two-step relay, now operates the remainder of its contact springs to cut-off its own winding from the line. This action is called CLEARING the line of attachments. The connector switch sends dial tone to the calling party to indicate that the connector circuit

is ready to receive the dialed impulses and the call proceeds as previously explained.

Only one linefinder is shown in figure 9-6. In practice the 25 linefinders furnished for the 100-line system are arranged in two groups designated A and B with each group equipped with its own finder control and distributor equipment. Group A consists of linefinders 1 through 13 and group B consists of linefinders 14 through 25.

BASIC SELECTOR SYSTEM

The system described in figure 9-6 has a capacity of 100 lines. It will serve any number less than 100, such as 50 or 25 lines. The number of lines to be served is wired to only the required finder and connector banks. In step-by-step systems of more than 100 lines a selector is introduced between the finder and connector switches. The mechanical structure of the selector is similar to a linefinder and connector. It has the same familiar bank, wipers, and mechanism to step the wipers up and in. The selector faces forward toward the called line as does the connector. A linefinder and a selector permanently connected to each other constitute a linefinder-selector link.

The 400-line shipboard dial telephone system is divided into four boards of 100 lines each. Each board is served by a group of connectors the banks of which are in multiple with each connector having access to all the lines in its board. The purpose of the selector is to choose the proper group of connectors and then hunt for an idle connector in that group. The group selection, or the vertical stepping of the selector, is controlled by the dial at the calling telephone. The rotary motion, or the trunk-hunting action, is controlled by the rotary interrupter springs of the selector.

The banks of the selector switch furnish facilities for a maximum of 100 trunk connections. In the 400-line system, only 90 connections are used on any one selector bank. In other words, only 9 of the 10 levels are used because the first level of all selectors are busied out. Because the linefinder wipers are connected permanently to the wipers of the associated selector, when the linefinder finds the calling line, the calling line is thereby extended to the wipers of a selector. Thus, a selector may become associated with any line in a particular board.

A basic selector system is illustrated by the block diagram in figure 9-7. For simplicity, only one link and only one connector in each of the four boards are shown. After the finder switches the calling line through to the selector, the first digit dialed by the calling party steps the selector up to a certain level. The selector then steps around automatically until it finds a nonbusy contact. This contact leads to an idle connector from which the connection to the called line is made by the next two dialed digits.

The banks of the finders are multipled, and all the lines in the 200 board, for example, have an appearance in the banks of the finders in the 200 board. The selector banks are also multipled, but instead of telephone lines being connected to the multiple, a certain number of individual connectors in each board are connected in multiple. The connectors, in turn, have their banks multipled, and the conductors from the connector banks are connected to individual telephone lines, called line normals.

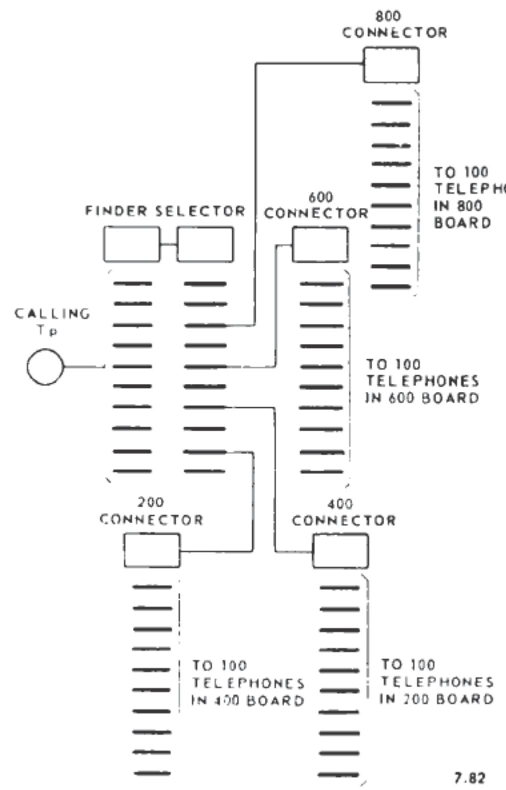


Figure 9-7.—Block diagram of basic selector system.

Each pair of linefinder line wipers is connected to a pair of selector line wipers. The wipers of the linefinder "look backward" ready to find any line in a particular board desiring to make a call and the wipers of the selector "look forward" ready to connect to the dialed group of connectors. The wipers of the connectors also "look forward" ready to connect to the dialed line. Because the linefinder link is busied for the duration of the conversation, only as many simultaneous conversations can take place as there are finder-selector links.

All the lines in the 200 board, for example, have an appearance in the linefinder multiple so that any idle finder in the 200 board can step its wipers up and around to locate any one of 100 lines which desires to make a call. Likewise the finder's associated selector can step its wipers up and around to complete a connection to any one of 40 connectors. One of the connectors will then step its wipers up and around (under control of dial impulses from the calling telephone) to complete a connection to any one of the 100 lines in its board. In each board there are 25 linefinders permanently connected to 25 selectors. In each board there are also 25 connectors and these connectors are available to selectors in any board. In the complete system there are 100 linefinders, 100 selectors, and 100 connectors, which makes possible a maximum of 100 simultaneous conversations.

To call telephone 659 from telephone 432, remove the handset from the cradle switch at telephone 432. The line-and-cut-off relay 432 associated with the calling line marks the calling line in the linefinder bank multiple and starts the group relays which control the finder, the finder automatically steps its wipers up and around until it finds the calling line. With the linefinder wipers resting on the set of contacts associated with the calling line, the calling line 432 is extended to the selector wipers. The selector sends dial tone to the calling party to indicate that the selector circuit is ready to receive the dialed impulses.

The calling party at telephone 432 dials number 659. When the digit 6 is dialed, the selector switch wipers will step up to the sixth level, then step around to hunt for an idle connector trunk in the 600 board. When a nonbusy trunk is found, the wipers will come to rest and extend the line of telephone 432 to the connector. Trunk-hunting action takes place after the digit 6 is dialed. This action is so rapid that the calling line is switched through to the connector before the next digit 5 is dialed.

After the selector has switched the line of telephone 432 through to a connector, the connector is ready to receive the dialed impulses of the last two digits. When the digits 5 and 9 are dialed, the connector switch wipers will step up and around and come to rest on the 59 set of contacts. The connection is now completed from telephone 432, through the finder-selector link, the connector, and over the line normals to telephone 659. The connector switch now tests line 59, and if the telephone is not in use, ringing current is sent out over the line to operate the ringer associated with telephone 659. When the handset at telephone 659 is removed from the cradle switch, ringing current is cut off and the talking circuit is completed between telephones 432 and 659. If, however, telephone 659 is in use, busy tone is sent back to telephone 432 to indicate that the called line is in use and that the calling party should hang up and try again later.

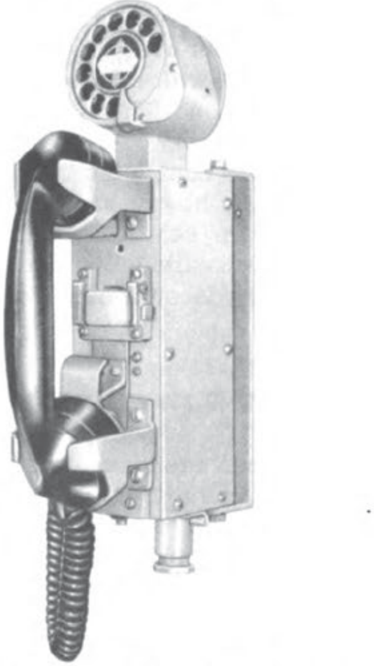
TELEPHONE STATION EQUIPMENT

The telephone instrument is a compact unit designed for transmitting and receiving speech, and for signaling the desired station. It consists essentially of a transmitter, receiver, dial, and ringer. The transmitter provides the means for changing sound into an undulating current that may be transmitted over an electrical circuit. The receiver provides the means for changing the undulating current back into sound. The dial, when operated, causes a series of interruptions (impulses) in the current flowing in the line circuit. The ringer provides an audible signal when the station is called.

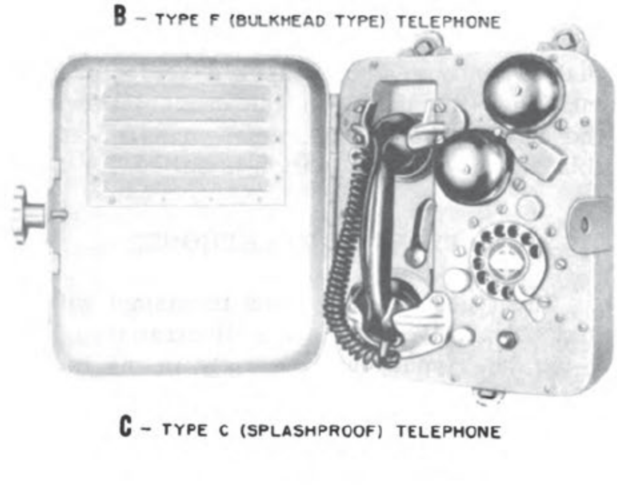
TYPES OF TELEPHONES

The types of telephones furnished with the dial telephone system are illustrated in figure 9-8. The types differ mainly in the form in which the components are assembled. The components perform the same function, but the form and mounting for each type is of special design and depends on whether the instrument is to be used in a protected or an exposed location.

A — TYPE A (DESK SET) TELEPHONE



B — TYPE F (BULKHEAD TYPE) TELEPHONE



C — TYPE C (SPLASHPROOF) TELEPHONE

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Figure 9-8.—Telephones.

The TYPE A desk set telephone (fig. 9-8, A) is installed in staterooms, cabins, offices, and similar stations. The desk set consists of a phenolic case (containing the ringer, dial, and other working parts), a handset, and connecting cord with a terminal block for making the line connections.

The TYPE F bulkhead telephone (fig. 9-8,B) is installed in all stations except those on weather decks and those designated as type A stations. The type F telephone is a nonwatertight unit designed for mounting on a bulkhead or on the side of a desk. It consists essentially of a metal housing on which are mounted the handset, dial, and ringer. The line connections are made at a terminal block inside the housing.

The TYPE C splashproof telephone (fig. 9-8, C) is installed at stations on weather decks and other stations exposed to moisture. The type C telephone is designed for bulkhead mounting and consists essentially of a metal housing on which are mounted the handset and dial which are enclosed in a splashproof box. The connections to the line are made at a terminal strip inside the housing.

The main assemblies that comprise a telephone instrument are the handset and base.

HANDSET

The standard handsets (fig. 9-9) used for the type A, type F, and type C telephones are identical. The handset consists of a conveniently shaped handle with two mounting cups, one for the transmitter and the other for the receiver. The mounting cups are at an angle with the handle to bring the transmitter the proper distance from the lips, for the average user, when the receiver is centered on the ear.

The transmitter and receiver are held in the mounting cups by an ear cap for the receiver and a mouthpiece for the transmitter. Both retaining pieces screw on the handset handle. In order to prevent the possibility of inserting the transmitter into the receiver mounting cup and vice versa, the transmitter is made to fit only into the transmitter cup, and the receiver to fit only into the receiver cup.

The transmitter and receiver units are both of the capsule type. Connections from the cord conductors are brought out to contact spring clips in the mounting cups of the handset. The connection between the transmitter or receiver

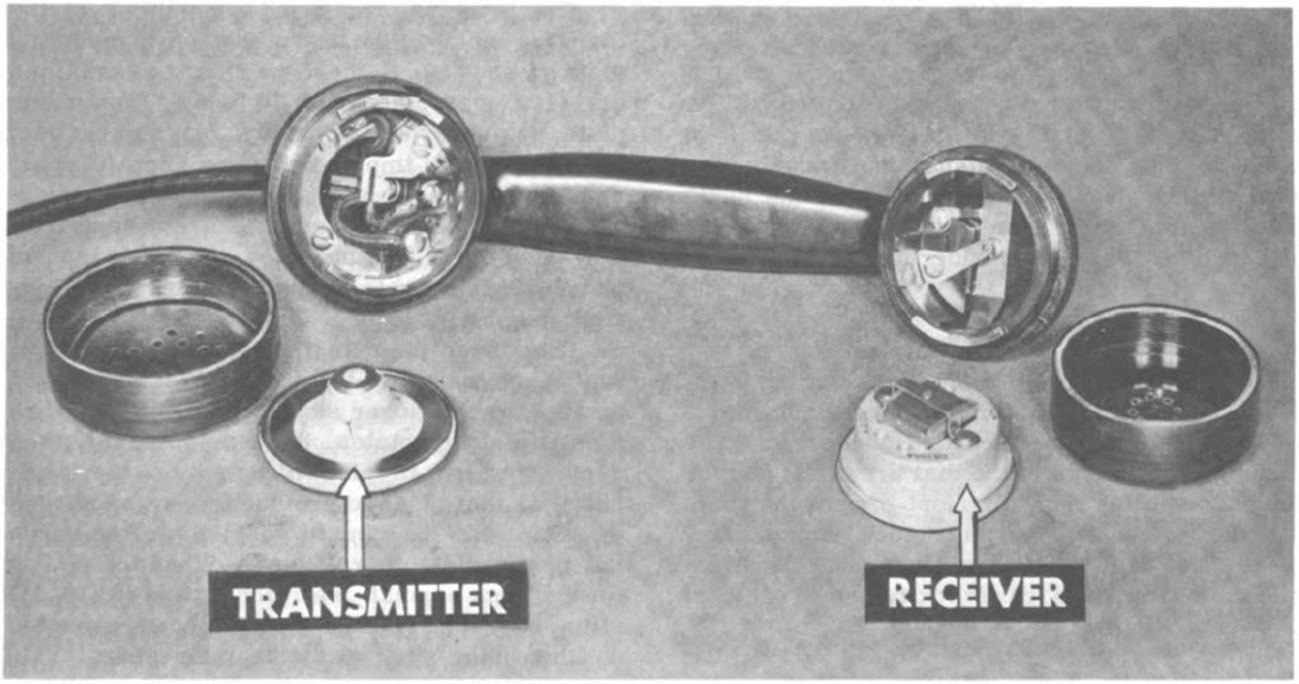

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Figure 9-9.—Telephone handset.

unit and the cord conductors is completed when the capsule is in contact with the contact spring clips.

Transmitter

The transmitter unit consists essentially of a metal diaphragm and an insulating cup containing loosely packed carbon granules. As soon as the handset is removed from the cradle, or hook switch, direct current supplied by the common battery at the switchboard flows through the transmitter. The diaphragm is mechanically connected to the carbon button so that sound waves striking the diaphragm cause it to vibrate. The mechanical movements of the diaphragm are transmitted to the carbon granules. When the carbon granules are compressed by an inward movement of the diaphragm, the resistance is lowered and more current flows through the transmitter. When the diaphragm relaxes, the pressure on the carbon granules is reduced, the resistance is increased, and less current flows. Thus, as long as the diaphragm is vibrating from the sound waves, the resistance of the carbon granule chamber is constantly changing, which in turn causes the current through the transmitter to undulate accordingly. This undulating current, called the VOICE CURRENT, is sent out on the telephone line after being boosted by the action of the induction coil and talking capacitor (explained later). The receiver at the other end of the line converts the voice current back into sound waves.

Receiver

The receiver unit is of the permanent magnet polarized type. It consists essentially of a powerful permanent magnet with two soft-iron coil-wound pole pieces and a diaphragm contained in a protective shell. The diaphragm is mounted under a slight tension so that it is pulled toward the pole pieces by the permanent magnet. The voice currents, flowing through the coils about the two pole pieces, set up magnetomotive forces that alternately aid and oppose the magnetic flux of the permanent magnet. This action causes the receiver diaphragm to be attracted with alternately greater and lesser force. As the diaphragm moves back and forth it reproduces the vibrations of the distant transmitter, and the sound waves thus produced are heard at the other end of the telephone connection.

BASE

The base includes the dial, hook switch, ringer, two capacitors, and induction coil. The type A, type F, and type C telephones (fig. 9-8) include the same combination of parts and assemblies, but the bases on which the parts are mounted differ somewhat, and the mounting arrangement differs considerably.

Dial

The dial (fig. 9-10) enables the calling party to control the automatic switching mechanisms which establish the telephone connection. The principle functions of the dial are to (1) deliver impulses to the line, (2) short-circuit the parts of the telephone that introduce unnecessary resistance in the dialing circuit, and (3) prevent the dialed impulses from clicking in the receiver.

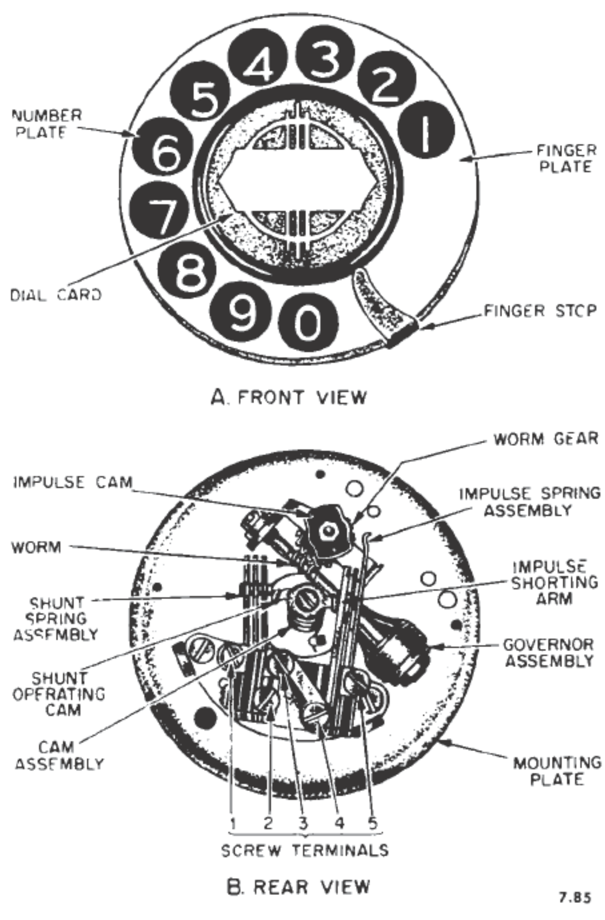

Figure 9-10.—Telephone dial.

The principal parts and assemblies of the dial are compactly assembled on a mounting plate (fig. 9-10). These parts and assemblies are (1) finger plate (with 10 holes), (2) number plate, (3) governor assembly, (4) impulse cam and springs, (5) impulse shorting arm, (6) shunt cam and springs, and (7) driving mechanism. The dial parts and assemblies are arranged so that when the dial is operated, the line is opened and closed at a rate of approximately 10 interruptions per second.

The finger plate is fitted to the main shaft, which rotates when the dial is turned from any number to the finger stop (fig. 9-10). Thus, as the main shaft rotates, the tension of the main spring, which is also mounted on the main shaft, is increased to provide the power needed to return the dial (main gear) to normal when the finger plate is released. When the dial is turned from normal, the ratchet pawl (fig. 9-11) slips over the ratchet gear which is mounted on the main shaft with the main gear. This prevents the main gear from rotating. When the dial restores to normal, however, the ratchet pawl engages the ratchet gear and the main gear rotates.

The speed of the dial mechanism as it returns to normal under the spring tension is controlled by the GOVERNOR ASSEMBLY. The governor assembly consists of a worm gear shaft that is mechanically connected to the main gear of the

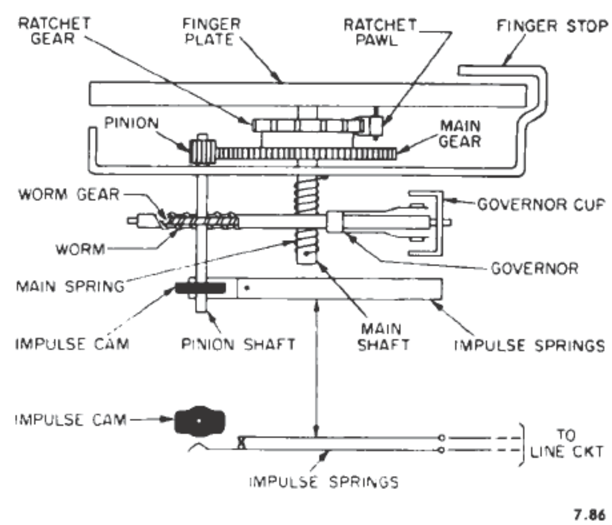

Figure 9-11.—Telephone dial schematic (shunt cam, shunt spring assembly, and impulse shorting arm, (not shown).

dial through a gear train (fig. 9-11). Two flyball wings are attached to the worm gear shaft. A governor weight on the end of each flyball wing protrudes into the governor cup. The rotary motion of the shaft causes the flyball wings to attempt to fly outward, but because of centrifugal force, friction is set up between the governor weights and the governor cup. The speed of the dial is thus regulated by adjusting the flyball wings to increase or decrease the amount of pressure the governor weights exert on the inside surface of the cup.

The IMPULSE CAM is geared mechanically to the main gear through a gear train (not shown) so that the impulse cam is caused to rotate during the time the dial mechanism is being returned to normal. The impulse springs are normally closed and are opened intermittently by the impulse cam only when the dial is returning to normal. An impulse is produced each time the impulse springs are opened. The travel from any off normal position is one series of impulses. The number of impulses in the series depends on how far the dial is turned away from normal. As the impulse cam rotates it opens the impulse springs, and thus the line circuit, the same number of times as the digits dialed. The momentary opening of the line circuit produces the dial impulses that actuate the automatic switching mechanisms (Strowger switches) at the telephone switchboard to extend the connection to the line associated with the dialed number.

The dial has a time delay feature that separates the series of dial impulses. The time delay is the time between the last impulse of a series and the complete restoring of the dial. It is approximately equal to the time required for one impulse and is accomplished by the movement of the impulse springs away from the cam by the cam shunt assembly. The last time the cam passes, no impulse is produced. The purpose of the delay feature is to allow the relays in the Strowger switches to operate properly between each series of impulses.

The SHUNT OPERATING CAM (fig. 9-10) is mounted on the main shaft. When the dial is at normal, the shunt cam holds the shunt springs in the normally open position. When the dial is turned off normal, the shunt cam is moved out of engagement with the shunt spring assembly and the shunt springs close to shunt the receiver and transmitter. The closure of the shunt springs prevents the impulses from being heard in the receiver during dialing, and also prevents the variable resistance of the transmitter from affecting the character of the dial impulses.

Hook Switch

A representative telephone station circuit is illustrated in figure 9-12. It is not desirable to have both the talking apparatus (transmitter and receiver) and the signaling apparatus (ringer and capacitor, C1) connected to the line while the telephone is in use. Accordingly, the hook switch, also called the cradle switch, monophone switch, or plunger switch (fig. 9-12) is an assembly of springs arranged so that removing or replacing the handset brings about the desired circuit changes. When the handset is placed on the hook switch, the ringer is connected to the line through C1, and the transmitter, receiver, and dial are disconnected from the line. When the handset is removed from the hook switch, a pair of make contacts and a set of break-make contacts on the switch (1) connect the transmitter, receiver, and dial to the line; (2) disconnect the ringer from the line; and (3) connect C1 across the dial impulse springs. The hook switch on the type A, type F, and type C telephones has the same function, but the mechanical arrangement differs.

Ringer

The ringer (fig. 9-13) is of the polarized, untuned type commonly called the STRAIGHT-LINE ringer (bell). It is suitable for use on both individual and party lines and is called UNTUNED because it will operate over a wide range of frequencies.

The ringer consists of a hard-steel permanent magnet, a soft-iron electromagnet, a pivoted armature carrying a clapper rod and clapper, and a gong or set of gongs. The electromagnet is U-shaped with a coil around each leg. The soft-iron armature is pivoted at its center, and lies in front of the two poles of the electromagnet, but does not quite complete the magnetic circuit. The permanent magnet is used to polarize the armature ends of the electromagnet. The armature end of each coil has a consequent north polarity produced by the permanent magnet. The two ends of the armature have consequent south poles produced by the permanent magnet.

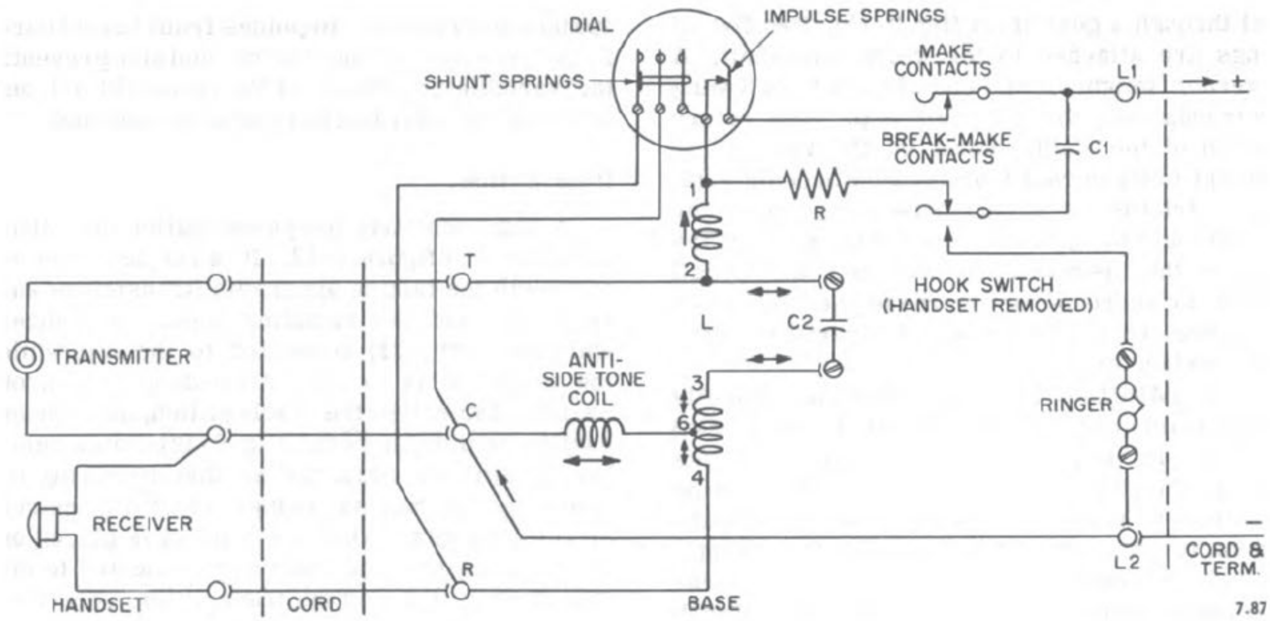

Figure 9-12.—Schematic diagram of telephone C circuit.

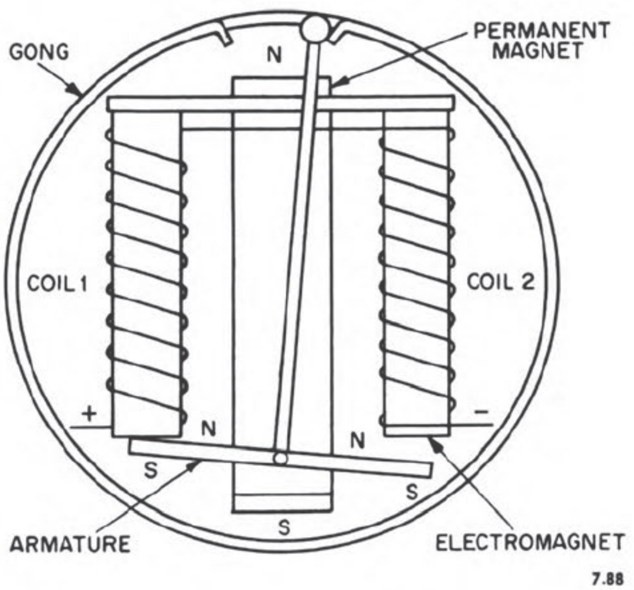

Figure 9-13.—Polarized ringer.

The coils are wound on the pole pieces so that when current flows in one direction (fig. 9-13) the mmf of coil 1 aids the permanent magnet flux and the mmf of coil 2 opposes it. Thus, coil 1 increases the strength of the north pole at the armature end of coil 1 and coil 2 attempts to establish a south pole at the armature end of coil 2. Because like poles repel and unlike poles attract, the armature moves clockwise and the clapper strikes the gong at the right.

When the ringer current reverses, the mmf of the coils reverses. Thus, coil 2 strengthens the north pole at the armature end of coil 2 and coil 1 attempts to establish a south pole at the armature end of coil 1. The armature moves counterclockwise and the clapper strikes the gong at the left. The gongs ring once for each half cycle of ringing current. The ringing current is 20 cycles per second.

When no current flows through the coils, the armature south poles attract the north poles at the armature end of the coils and the clapper moves either to the right or the left depending on which air gap is the shortest. A biasing spring (not shown) is provided to give the armature a definite position when the gongs are silent. This spring holds the clapper against one gong and prevents the gong from tingling when the other party on the line is dialing (biasing springs on commercial telephones prevent clapper operation when the wrong polarity of ringing current is received in selective ringing on four-party lines). Small

pieces of nonmagnetic material are placed between the core ends and the armature to prevent actual contact and subsequent sticking due to residual magnetism.

Capacitors

Two capacitors are used in the telephone, one in the ringing circuit and one in the transmission circuit (fig. 9-12). The capacitor C1 in the ringing circuit allows a-c ringing current to pass through the ringer and prevents the flow of direct current. During dialing C1 (in series with R) is shunted across the dial impulse springs to minimize sparking and suppress radio interference. The capacitor C2 in the transmission circuit improves the transmission output characteristics of the telephone. If capacitor C2 were not used, the output would be very low because of the high impedance of the telephone circuit and the line circuit. The action of C2 is explained later.

Induction Coil

The induction coil L couples the transmitter and receiver units to the line (fig. 9-12). It also increases the output volume by boosting the voice current undulations developed by the transmitter and prevents or decreases SIDETONE. Sidetone occurs when a person hears his own voice in the receiver while talking into the transmitter.

The induction coil L consists of three windings (1-2, 3-6, and 6-4) on a laminated iron core. The windings are magnetically interlinked by the common magnetic circuit provided by the iron core. The induction coil serves as a 3-winding autotransformer in which part of the winding is common to both the primary (input) and the secondary (output) circuits. Any change in the current in one of the windings causes a corresponding induced emf in all three windings. The core is made up of high permeability laminations to provide a low reluctance path for the magnetic flux. A small air gap in the magnetic circuit prevents saturation of the core by the direct current feeding the transmitter.

TELEPHONE CIRCUIT

A telephone circuit (fig. 9-12) comprises the ringing, dialing, transmission, and receiving circuits. Booster and antisidetone features are also included in the circuit. Note that the handset is removed from the hook switch so that the transmitter, receiver, and dial are connected to the line, and the ringer is disconnected from the line.

Ringing Circuit

The ringing circuit consists of line L1, ringing capacitor C1, make-contacts on the hook switch, the ringer, and line L2, (fig. 9-12). This circuit condition exists when the handset is placed on the hook switch. When the handset is removed from the hook switch, the ringing capacitor C1 is transferred from the ringer to the dial impulse springs, as previously mentioned, to prevent excessive sparking at the contacts of the impulse springs.

Dialing Circuit

The dialing circuit consists of line L1, the hook switch, the dial impulse springs (shunted by resistor R and capacitor C1, in series), the dial shunt springs, and line L2 (fig. 9-12). When the dial is operated, the dial shunt springs close to shunt the transmitter, receiver, and induction coil so that they will not affect the impulses sent out by the dial.

Transmission Circuit

The transmission circuit includes two distinct circuits, the main talking circuit, and the local talking circuit. The MAIN TALKING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-12). The LOCAL TALKING CIRCUIT consists of the transmitter, capacitor C2, winding 3-6 of the induction coil, and the antisidetone coil (fig. 9-12). This circuit is designated "local" because the circuit is completed within the individual telephone and not through the line conductors.

The main talking circuit is also the d-c path through the telephone. The direct current for the transmitters of the calling and called telephones is furnished by the automatic switchboard through relays in the connector switch (not shown) which establish the connection.

When talking into the transmitter, two sets of current undulations are set up: (1) those

directly produced in the line due to the variations in the resistance of the transmitter: and (2) those produced in the local talking circuit by the charging and discharging of capacitor C2, caused by the varying potential drop across the transmitter.

The local talking circuit current undulations are best understood if it is kept in mind that the capacitor C2, is connected across the transmitter, directly on one side and through winding 3-6 of the induction coil and the antisidetone coil on the other side. Thus, the resistance variation introduced by the action of the transmitter causes the voltage to vary on the plates of capacitor C2. Alternating currents will then flow in the local talking circuit as the capacitor C2 adjusts the charge on its plates to the varying difference of potential across the transmitter.

The resulting alternating currents flowing in winding 3-6 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary winding 1-2. The change in current that occurs in winding 1-2 is of greater magnitude as a result of the change of produced current in winding 3-6 by the transmitter. The induced voltage in winding 1-2 aids the voice currents directly delivered to the line via the main talking circuit and thus a BOOSTER feature is achieved.

It is important that the transmitter of the calling telephone produces a large effect on the receiver of the called telephone and little or no effect on the local receiver. Accordingly, the telephone circuit is designed so that the local transmitter action produces a minimum of current flow through the local receiver. The means used to lower sound in the local receiver, introduced at the local transmitter is called the antisidetone feature.

The antisidetone feature is obtained by matching the impedance of the local talking circuit to the impedance of the main talking circuit (including the line loop). Because the line conditions vary with different lengths of line, the impedance of an average line loop is used as a standard, and the impedance of the local circuit is arranged to balance the average line loop. If any line loop is shorter or longer than the average loop, the sidetone will tend to increase.

When transmitting, winding 3-6 is the primary of the autotransformer and winding 1-2 is the secondary. Winding 6-4 is inductively coupled to the transmission circuit, and voltage is induced in winding 6-4 that opposes the change in transmission current. The desired inductive balance is obtained by the impedance of the antisidetone coil so that a minimum of voltage exists across the receiver terminals, resulting in little or no sound in the receiver during transmission. This action automatically makes the talker increase the intensity of his voice and thus increase the signal-to-noise ratio.

Receiving Circuit

The receiving circuit also includes two distinct circuits, the main receiving circuit, and the local receiving circuit. The MAIN RECEIVING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-12). This circuit is the same as the main talking circuit during transmission, except winding 1-2 now becomes the primary of the autotransformer instead of the secondary. The LOCAL RECEIVING CIRCUIT includes capacitor C2, windings 3-6 and 6-4 of the induction coil, the receiver, and transmitter (fig. 9-12). As previously explained, the antisidetone feature prevents the local transmitter from affecting the receiving circuit.

During the reception of speech, the voice currents are received via the main talking circuit which include line L1, winding 1-2 of the induction coil, the transmitter, and line L2. The voice currents flowing in winding 1-2 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary windings 3-6 and 6-4. (Because of the antisidetone feature the local transmitter has no effect on the receiving circuit.) The a-c voltage induced in windings 3-6 and 6-4 causes signal currents to flow through the receiver which (by action of the diaphragm) reproduces the tone and words of the person speaking into the transmitter at the other end of the connection.

TELEPHONE CONNECTIONS

All telephones are provided with screw-type terminals and therefore soldering is not necessary in order to connect or replace a telephone. All conductors are color-coded and the correct termination for each conductor is shown in terms of the color code on the circuit label inside the telephone base or on the wiring diagram.

When changing or replacing any wiring in or to a telephone, check the new connections against the circuit label inside the telephone or the applicable wiring diagram.

The several types of telephones can be connected for one-party service or two-party service. For a ONE-PARTY line two conductors are required to extend the connection between the telephone instrument and the automatic switchboard. These are the line conductors designated L1 and L2 on the circuit labels and telephone wiring diagrams. On a one-party line the ringer is across the line and the line conductors are also the conductors for the ringer circuit. This arrangement is called METALLIC RING.

For a TWO-PARTY line three conductors are required to extend the connection between the telephone instrument and the automatic switchboard. The two line conductors are designated L1 and L2 and the third conductor, which is connected to a ground (positive battery) common to all ringer circuits in the shipboard dial telephone system, is designated G.

When two telephones are connected electrically to the same line circuit, their ringers cannot be connected across the line but must be arranged so that ringing current will operate only the ringer of the called telephone. Thus, to obtain separate ringer circuits for the two telephones, the ringer of one telephone is connected between the positive line conductor L1, and ground (positive ring), whereas, the ringer of the other telephone is connected between the negative line conductor L2, and ground (negative ring). This arrangement is called GROUND RING.

Therefore, on party lines it is necessary that the ringers be connected to the proper side of the line. The telephone system is arranged so that the side of the telephone line on which ringing current is applied is determined by the telephone number. Telephones assigned numbers starting with even digits have ringers connected between the positive side of the line (L1) and ground. On the other hand, telephones assigned numbers starting with odd digits have ringers connected between the negative side of the line (L2) and ground.

Type A Telephone

The type A telephone (fig. 9-14) is equipped with a terminal subassembly inside the base and a line-and-cord terminal block on the end of the desk set cord. The line wires L1 and L2, from the automatic switchboard terminate at the line-and-cord terminal block and the wiring of the telephone instrument terminates at the instrument terminal subassembly. The desk set cord extends the connection between the telephone wiring at the instrument subassembly and the line wiring at the line-and-cord terminal block.

The type A telephone is connected for ONE-PARTY line service (metallic ring) by connecting at the line-and-cord terminal block, the red-coded and white-coded wires to terminal L2, and the black-coded wire to terminal L1. Proper operation of the ringer is determined by dialing, from a nearby telephone, the number assigned to the telephone just connected. The ringer should ring.

The type A telephone (fig. 9-14) is connected for TWO-PARTY line service (ground ring) by connecting, at the line-and-cord terminal block, the black-coded line wire to terminal L1, the white-coded line wire to terminal L2, and the red-coded ground wire to terminal 4G. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line wire connections at the line-and-cord terminal block. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, remove the base plate and reverse the ringer terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing springs. The biasing springs should be as nearly parallel as possible to the ringer coil cores. To increase the tension in the biasing springs bend the lower mounting lug (not shown) downward with a pair of pliers. Repeat the test.

Type F telephone

The type F telephone (fig. 9-15) is equipped with a terminal subassembly mounted on the bottom cover plate inside the telephone housing. The ship's cable, consisting of line wires J95 and JJ95, battery-connected wire JJ9, and ground-connected wire J9, enters through a terminal tube at the bottom of the housing.

The type F telephone is connected for ONE-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal L2, the line wires J95 and JJ95 to

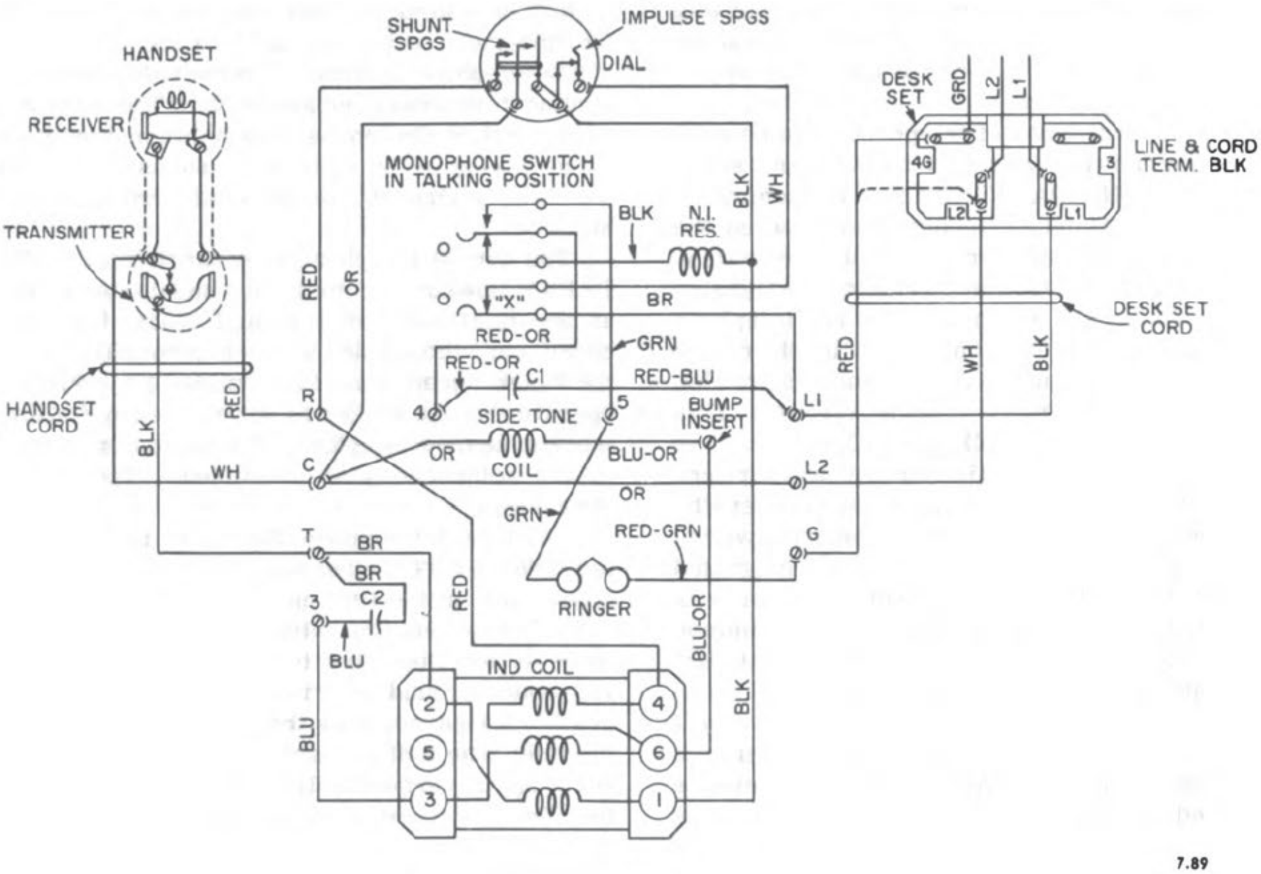

Figure 9-14.—Type A telephone wiring diagram.

terminals L1 and L2, respectively, the ground-connected wire J9 to terminal G, and the battery-connected wire JJ9 to terminal B. Remove the handset from the hook switch. The dial lamp should light and a dial tone should be heard. From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring.

The type F telephone (fig. 9-15) is connected for TWO-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal G, and the ship's cable wires J95, JJ95, J9, and JJ9 to terminals L1, L2, G, and B, respectively. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the red-blue and the red-orange ringer connections at terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing spring (not shown) by bending the end mounting lug with a pair of pliers. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard. Replace the handset.

Type C Telephone

The type C telephone (fig. 9-16) is equipped with a terminal subassembly and a terminal block inside the housing. This ship's cable, consisting of wires J95, JJ95, J9, and JJ9 are connected to L1, L2, G, and B, respectively, on the terminal block. The wires L1, L2, G, and B on the terminal block are connected to corresponding terminals on the terminal subassembly.

The type C telephone is connected for ONE-PARTY line service by connecting, at the

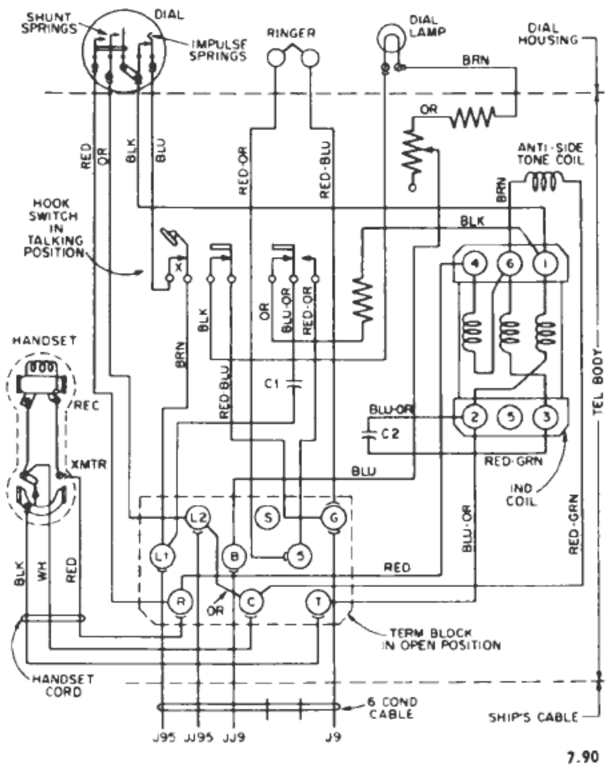

Figure 9-15.—Type F telephone wiring diagram.

terminal subassembly, the red-blue ringer wire to terminal 4 (L2). From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.

The type C telephone (fig. 9-16) is connected for TWO-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal 3 (G). From a nearby telephone, dial the number assigned to the telephone just connected. If the telephone ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the ringer connections at terminals 3 and 5 on the terminal subassembly. Repeat the test. If the ringer still taps, increase the tension of the biasing spring as previously explained. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.

POWER SIGNAL RELAY

As previously stated, when a telephone is installed in a noisy location, the telephone may be connected through a power signal relay to an extension signal. The extension signal used with the dial telephone system is a 115-volt 60-cycle motor-operated horn.

The power signal relay (fig. 9-17) includes: (1) coil subassembly, (2) core subassembly, (3) armature, (4) microswitch, and (5) terminal subassembly enclosed in a steel case.

The COIL SUBASSEMBLY consists of a bakelite frame on which is wound a coil of wire. The CORE SUBASSEMBLY consists of a number of U-shaped laminations riveted together. Two brass brackets are riveted to one leg of the core for mounting the armature subassembly and the relay terminals. The coil subassembly is attached to the other leg of the core.

The ARMATURE completes a magnetic path between the two poles of the coil subassembly and actuates the snap-action microswitch. It is provided with a brass residual pin to maintain a small space between the armature and core to prevent sticking.

The MICROSWITCH is provided with large contact surfaces so that large currents can be controlled with relatively small movements of the armature.

The TERMINAL SUBASSEMBLY is provided with terminals for making the connections to the a-c power source, the extension signal, and the telephone line.

The telephone ringer and the power signal relay are connected in parallel to the line of the telephone. The power signal relay has a pair of microswitch contacts, one of which is connected to one side of the extension signal and the other to the a-c power supply. The other side of the extension signal is connected permanently to the a-c power supply.

When the ringing current is applied to the line of the telephone through the winding of the connector relay F, the current energizes both the ringer at the telephone and the coil of the power signal relay. The coil of the power signal relay, when energized, actuates the relay armature to close the microswitch contacts. The microswitch contacts, when closed, complete the a-c power circuit to sound the extension signal. As soon as the handset is removed from the hook switch, the ringing current is

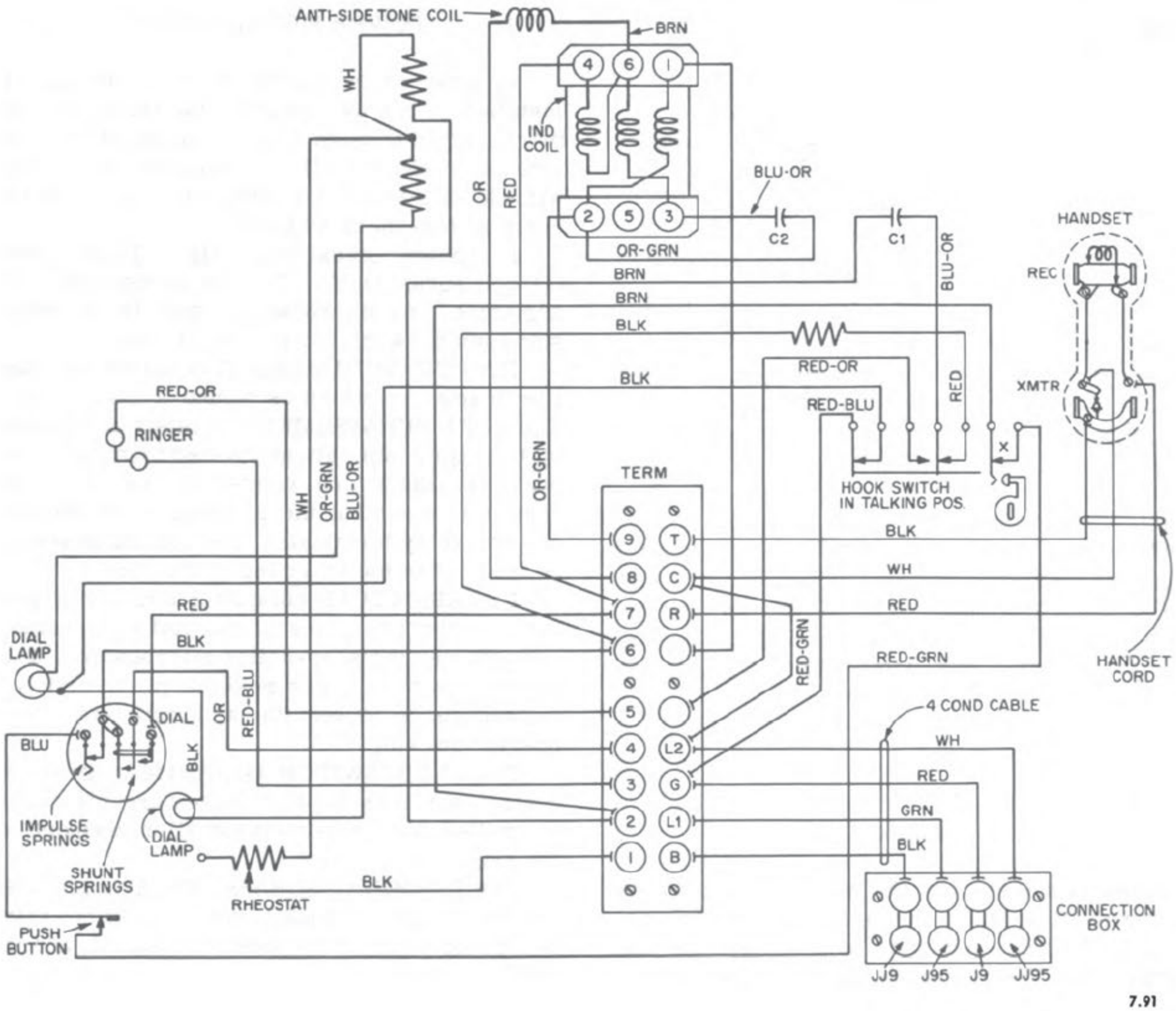

Figure 9-16.—Type C telephone wiring diagram.

removed from the line, the power signal relay restores, and the circuit to the extension signal is opened at the microswitch contacts.

Type F Telephone

When a type F telephone is installed in a noisy location, the telephone is connected through a power signal relay to an extension signal. When the telephone is arranged for extension signal ringing, it is recommended that the instrument be connected for ground ring irrespective of whether it is a one-party or two-party line, in order to eliminate any possibility of the extension signal being actuated during dialing.

At the terminal subassembly (fig. 9-15), connect the red-blue ringer wire to terminal G, the ship's cable wires J95, JJ95, J9 and JJ9 to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from the L1 to the L2 terminal. Repeat the test.

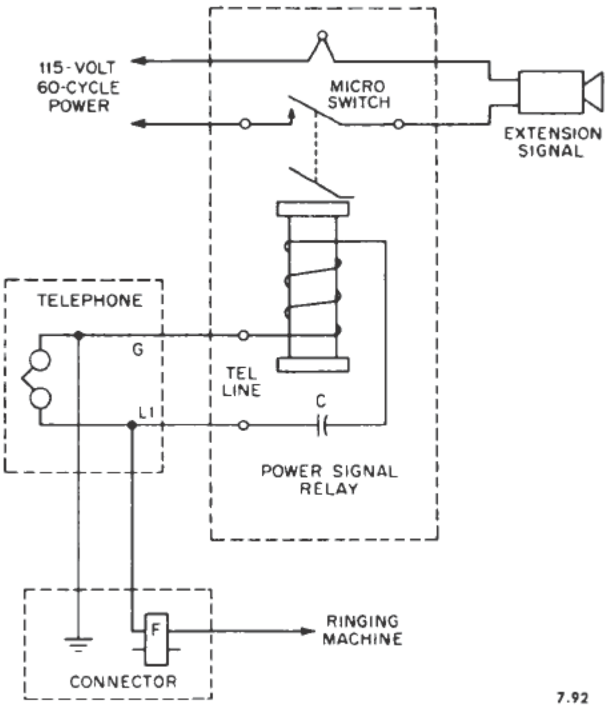

Figure 9-17.—Power signal relay.

Type C Telephone

When a type C telephone is installed in a noisy location, it is arranged for extension signal ringing and connected for ground ring irrespective of whether it is a one-party or two-party line.

At the terminal block (fig. 9-16) the ship's cable wires J95, JJ95, J9, and JJ9 are connected to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G. At the terminal subassembly, connect the red-blue ringer wire to terminal 3 (G) and the wires from the terminal block to the corresponding terminals, L1, L2, G, and B. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from terminal L1 to terminal L2. Repeat the test.

MAINTENANCE

If trouble is believed to be at the telephone instrument, but the location of the trouble is not known, first determine that the current from the switchboard is being delivered to the telephone instrument. If no current is reaching the telephone, the trouble is either in the line or at the automatic switchboard, and no further test of the telephone is necessary at this time. To test for current at the various types of telephones, place the 48-volt test lamp across terminals L1 and L2 of the terminal subassembly. If the test lamp lights, the line is delivering current to the telephone. Always pull the disconnect line key when performing any work on the telephone instrument other than replacing the transmitter or receiver.

In general, when it is necessary to work on a telephone, it should be taken out of service by disconnecting the line wires L1 and L2, which are connected to the terminal subassembly inside the instrument. Thus, access to the interior of the telephone must be gained to expose the terminal subassembly.

Receiver

If the trouble is indicated in the receiver, test the receiver by substituting a receiver known to be good for the receiver already in the handset. The receiver capsule is held securely in place by the ear cap. The connections to the electrodes are through springs. The receiver assembly cannot be repaired because the capsule cannot be opened without damage to the receiver. Hence, if the receiver is defective, remove the receiver capsule and insert a new capsule.

If the trouble is not corrected with a new receiver capsule in the handset, test the transmitter.

Transmitter

The transmitter is also tested by substituting a transmitter known to be good for the transmitter already in the handset. The transmitter capsule is held in place in the mounting cup by two retaining spring clips and is secured by the mouthpiece. The connections of the electrodes are through springs. The transmitter, like the receiver, cannot be repaired because the capsule cannot be opened without damage to the transmitter. Thus, if the transmitter is defective, remove the transmitter capsule and insert a new capsule. If the trouble is not cleared, test the handset cord.

The HANDSET CORD is tested for continuity with the mouthpiece and transmitter assembly removed from the transmitter mounting cup as previously explained. The transmitter mounting cup contains four screw-type terminals (not shown) designated B, W, OR, and R. With the telephone connected to the line wires L1 and L2, place the 48-volt test lamp leads across terminals R and B. If the test lamp does not light, replace the handset or the handset cord.

Handset

To remove the handset from the type A telephone (fig. 9-14) disconnect the desk set cord at the line-and-cord terminal block and remove the base plate. Free the handset cord from the cord clip (not shown) and loosen the handset cord terminals R, C, and T. Disengage the conductors and pull the cord through the opening in the telephone housing.

To connect the new handset to the type A telephone, thread the cord through the opening in the telephone housing. Check the circuit label inside the telephone for the color code of the cord conductors. Slip the terminal on each conductor under the proper screw terminal and tighten the screw. Work the handset cord under the cord clip with the screwdriver and position the clip to hold the cord securely. Replace the base plate on the telephone housing and reconnect the desk set cord at the terminal box.

Handset Cord

To remove the handset cord from the type A telephone (fig. 9-14) disconnect the handset cord and remove the transmitter assembly. Loosen the screw terminals designated OR, R, and B (previosuly mentioned) inside the transmitter mounting cup. Disengage the cord conductor terminals and pull the handset cord through the opening on the rear of the transmitter mounting cup.

To replace the handset cord, thread the handset end of the cord through the opening at the rear of the transmitter mounting cup. Note that the three conductors of the handset cord are fitted with spade terminals at both ends of the cord. However, the distance from the stay cord to the terminals is shorter at one end of the cord than the other. The shorter end connects to the handset housing and the longer end to the telephone housing. Slip the red- and orange-coded conductor terminals under the screw terminals designated R and OR, respectively, inside the transmitter mounting cup. Slip the brown-coded conductor terminal under the screw terminal designated B (on top of the spring). Tighten the terminals and fit the conductors down into the recess in the transmitter mounting cup.

Thread the other end of the three-terminal ended conductors of the cord through the opening in the telephone housing. Check the circuit label inside the telephone for the color code of the cord conductors. Slip the terminal on each conductor under its proper screw terminal, and tighten the screw. Work the handset cord under the cord clip with the screwdriver, and position the clip to hold the cord securely. Replace the base plate on the telephone housing, and connect the desk set cord at the terminal box.

Power Signal Relay

If the ringer of a telephone with which a power signal relay is associated rings but the extension signal does not sound, the trouble may be at the power signal relay assembly (fig. 9-17). To determine if the power signal relay is faulty, remove the front cover and (from a nearby telephone) dial the number of the telephone associated with the relay. While ringing current is being applied to the line of the associated telephone, observe the relay armature. If the armature appears to be operating, it is possible that the relay contacts are not making. Operate the armature by hand. If the extension signal sounds, check the adjustment of the relay.

If the relay armature does not operate, test for ringing current at the TEL LINE terminals. If ringing current is present at these terminals, it is possible that either the coil or capacitor is open, in which case the relay assembly should be replaced.

When trouble is experienced in the telephone that cannot be cleared by replacement of the handset, dial, or cords, replace the instrument with a spare telephone. Detailed information concerning the operation, care, and maintenance of dial telephone station equipment is contained in the manufacturer's technical manual furnished with the equipment, and in chapter 65 of the *Bureau of Ships Technical Manual*.

QUIZ

1. What is the function of the shipboard dial telephone system?
2. Why are the lines of the telephones that comprise a telephone system arranged at a central point?
3. In an automatic telephone system what device controls the switching mechanisms?
4. What action occurs with respect to the line current when a telephone dial is operated?
5. What determines the number of impulses sent out by the dial?
6. Name the equipments that comprise the dial telephone system.
7. Telephone station equipments are designed for mounting in what two general kinds of location?
8. What device may be provided with a telephone installed in a noisy location?
9. What major assembly comprises the switching center of the dial telephone system?
10. Name the three components that comprise the power equipment.
11. What is the purpose of the attendants cabinet?
12. Name the three major types of Strowger switches used in the shipboard dial telephone system.
13. What is the function of the linefinder?
14. Is the operation of the linefinder under the control of dial impulses?
15. What is the function of the selector?
16. How is vertical stepping of the selector controlled?
17. What is the function of the connector?
18. How is the connector mechanism actuated to step its wipers up and around to the set of contacts associated with the called telephone?
19. What device functions to apply ground to start the linefinder control relays hunting for the calling line?
20. When the first digit of a 3-digit number is dialed causing the selector to step vertically, what determines the side of the line on which ringing current will be impressed?
21. What action occurs with respect to the connector when the second and third digits are dialed?
22. How are Strowger switches interconnected so that any telephone in the system can connect with any other telephone in the system?
23. What constitutes a finder-connector link?
24. How many finder-connector links are usually furnished for a 100-line system?
25. What are line normals?
26. How many simultaneous conversations can take place on a 100-line finder-connector system (fig. 9-5)?
27. What does the finder control and distributor equipment do when the finder locates the calling line and switches through to the connector?
28. What action occurs with respect to the associated line-and-cutoff relay when the calling line is switched through to the connector?
29. What constitutes a linefinder-selector link?
30. What two functions does the selector perform?
31. How many simultaneous conversations can take place in the 400-line shipboard dial telephone system?
32. In the 400-line selector system, what function is performed by the selector when the first digit of the 3-digit number is dialed after the calling line has been extended to the selector?
33. Name the four essential components of a telephone instrument.
34. In what kinds of locations are type A telephones installed?
35. In what kinds of locations are type F telephones installed?
36. Where are type C telephones installed?
37. Name the two principle components that comprise the handset.
38. Name the six essential components that are included in the telephone base.
39. What is the function of the impulse cam in the telephone dial (fig. 9-5)?
40. What is the function of the automatic switching mechanisms (Strowger switches) at the telephone switchboard when a call is made?
41. What is the purpose of the time delay feature of the dial?
42. How are the impulses prevented from being heard in the receiver during dialing?
43. Is the handset placed on or removed from the hook switch to disconnect: (a) the transmitter, receiver, and dial from the line? (b) the ringer from the line?

44. Why is the telephone ringer called UNTUNED?
45. What is the purpose of the ringing capacitor C1?
46. What is the purpose of the capacitor C2 in the transmission circuit?
47. In addition to coupling the transmitter and receiver units to the line, name two functions of the induction coil.
48. Name the four circuits that comprise a telephone circuit.
49. What is the circuit called that comprises L1, C1, the make contacts of the hook switch, the ringer and L2?
50. What is the circuit called that comprises L1, the hook switch, dial impulse springs (shunted by R and C1 in series) dial shunt springs, and L2?
51. What is the circuit called that comprises L1, winding 1-2 of the induction coil, the transmitter, and L2?
52. What is the circuit called that comprises the transmitter C2, winding 3-6 of the induction coil, and the antisidetone coil?
53. Does the induced voltage in winding 1-2 of the induction coil (as a result of current variations in winding 3-6 produced by the transmitter) aid or oppose the voice currents delivered to the line?
54. What feature reduces the level of sound in the local receiver that originated in the local transmitter?
55. (a) What is the circuit called that includes L1, winding 1-2 of the induction coil, the transmitter, and L2? (b) What is the circuit called that includes C2, windings 3-6 and 6-4 of the induction coil, the receiver, and transmitter?
56. (a) How many conductors are required for a one-party line to extend the connection between the telephone instrument and the automatic switchboard, and (b) how are they designated?
57. (a) How is the ringer connected on a one-party line and (b) what is this arrangement called?
58. (a) How many conductors are required for a two-party line to extend the connection between the telephone instrument and the automatic switchboard, and (b) how are they designated?
59. What is the ringing arrangement called on a two-party line that permits ringing current to operate only the ringer of the called telephone?
60. How is the type A telephone connected for one-party line service?
61. How is the type A telephone connected for two-party line service?
62. How is the telephone just connected for two-party service tested for proper operation?
63. What procedure is first necessary to correct the condition that causes the ringer to tap at the telephone just connected for two-party line service when the other telephone on the line dials any telephone number?
64. What procedure is necessary to correct the condition if the ringer still taps after complying with question 63?
65. How is the type F telephone (fig. 9-9) connected for one-party line service?
66. What is the purpose of the power signal relay (fig. 9-11)?
67. When the telephone is arranged for extension signal ringing, why is the instrument connected for ground ring irrespective of whether it is a one-party or two-party line?
68. How is the type F telephone connected for extension signal ringing (fig. 9-9)?
69. What procedure is necessary to correct the condition that causes the extension signal not to operate when the number assigned to the telephone just connected is dialed from a nearby telephone?
70. If trouble is indicated in the receiver, how is it tested?
71. Why cannot a defective receiver be repaired?
72. When testing the transmitter cord for continuity, across which two terminals inside the transmitter mounting cup are the 48-volt test lamp leads placed?
73. Name two possible troubles if the power signal relay does not operate when ringing current is present at the TEL LINE terminals.

CHAPTER 10

CLOSED CIRCUIT TELEVISION

INTRODUCTION

Television is becoming increasingly important in Navy applications and many present day applications would have been considered impractical only a few years ago. For the future, some advanced thinkers envision TV communications between a flag ship and other ships in a task force so that conferences and briefings can take place without the actual physical presence of subordinate commanders.

Present applications are limited to closed circuit television. The difference between a closed circuit TV system and a commercial home TV system is principally in the method used to get the signal from the camera to the picture tube at the receiving location. In the closed circuit systems, signals are sent between the camera and the receiver through cables instead of through the air.

Basically, Navy closed circuit TV is an interior communications system and its maintenance will fall on the IC Electrician. Therefore, it is important that personnel who will be working with the equipment acquire a working knowledge of television.

No doubt about it, television in any form is a comprehensive subject. However, TV equipment is not as complex as it might seem when the overall operation is considered. The basic simplicity becomes apparent when a system is reduced to its individual components and the function of these components considered separately.

To present the subject in a logical manner, a simplified television system will be described with the aid of a block diagram.

A SIMPLIFIED TELEVISION SYSTEM

A block diagram of a standard home television system is shown in figure 10-1. There are three main divisions in the diagram. The top division represents the video or picture section. The central division represents the audio or sound section, and the lower division represents the television receiver.

In the video section, the camera tube provides a means of converting light rays from an object on which the camera is focused into electrical impulses. Light from the object is focused on the light sensitive surface (called the mosaic) in the camera tube by a lens system. The camera tube contains a means of generating and controlling a stream of electrons that is moved across the mosaic in such a manner that it traverses (scans) the mosaic line by line. As the beam strikes a spot in the mosaic it generates a small electrical impulse which corresponds to the light or dark portions of the image. The electrical impulses generated in this manner are sent to the video amplifiers.

Video amplifiers are designed to amplify a wide range of frequencies, and the weak electrical impulses from the camera tube are built up by the amplifier and fed to a control amplifier.

Circuits in the sync generator produce synchronizing (sync) pulses. These pulses are applied to the control amplifier and become a portion of the transmitted signal that controls horizontal and vertical scanning. Horizontal synchronization makes the horizontal scanning at the receiver occur at the same relative time as the horizontal scanning at the camera. Vertical synchronization makes the vertical scanning at the same relative time as the vertical scanning at the camera.

In the amplitude modulator, the carrier wave is modulated by the video sync and blanking pulses. The blanking pulses blank out the electron beam during the time that sync pulses are applied. The composite (total) signal is then amplified by the r-f amplifier and fed to the antenna for radiation into space.

The sound portion of the television signal is frequency modulated. The sounds are picked up by a microphone, amplified by the audio amplifier, and fed to the frequency modulator section. The sound carrier frequency is varied

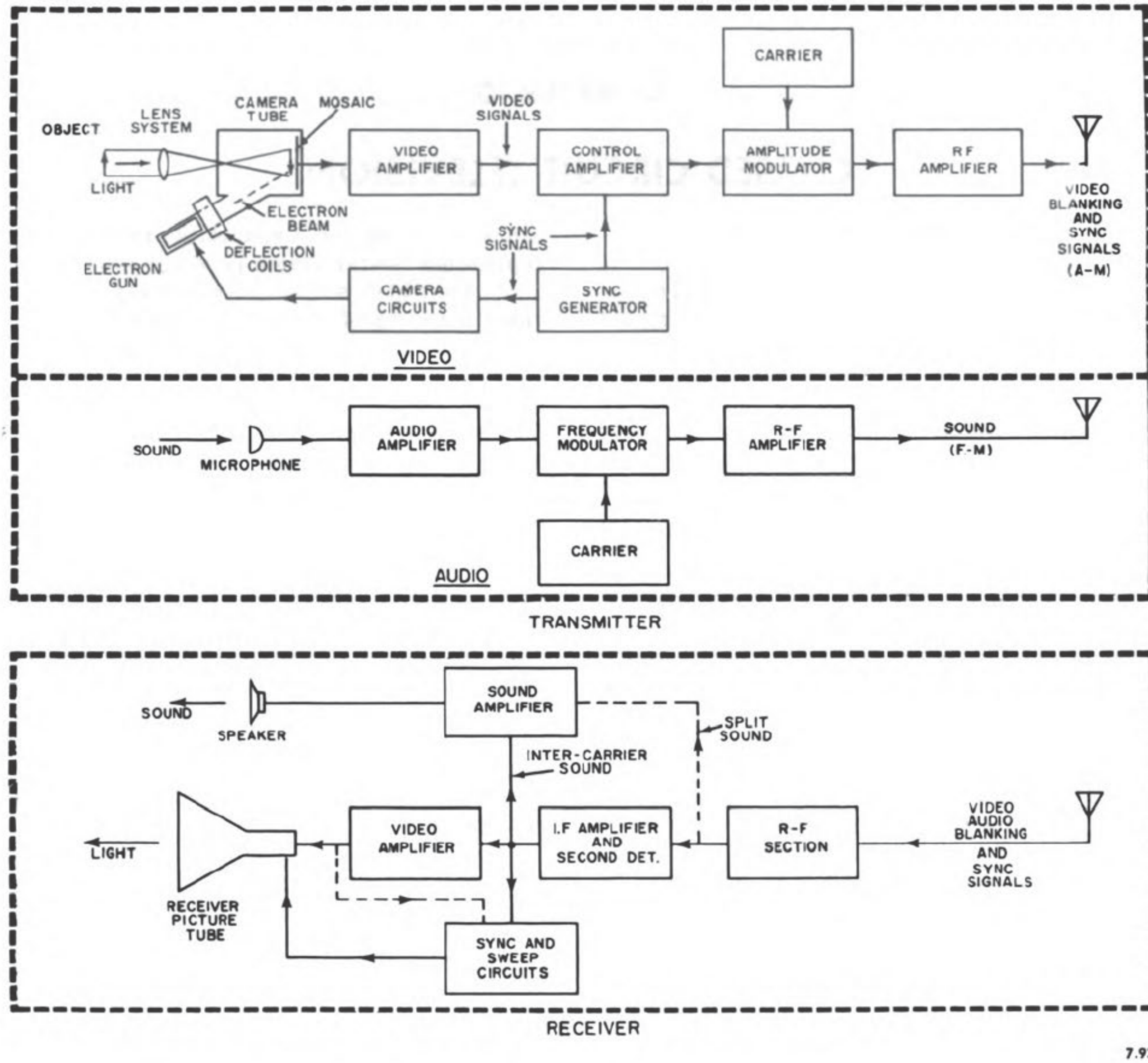

Figure 10-1.—Simplified block diagram of a television system.

according to the frequency of the audio signal that is being picked up by the microphone. The frequency modulated signal is then amplified by an r-f power amplifier and fed to the antenna for radiation into space.

The radiated video and sound frequencies are picked up at the receiving antenna. These frequencies contain the video, audio, blanking, and sync signals. The r-f section in the receiver (lower section, fig. 10-1) amplifies these signals. In some receivers (those employing split sound) the sound is picked off at the output of the r-f section and fed to a separate i-f amplifier. The i-f sound signal is then fed to an f-m detector. The output of the f-m detector is amplified by a conventional audio amplifier and fed to the speaker. In other receivers (those using intercarrier sound) the composite signal (video, sync, and audio) is fed through a common i-f amplifier system. At the output of the i-f system the signal is split and the sound fed to the audio amplifier, the sync signals are fed to the sweep circuits, and the video and blanking signals are fed to the video amplifier. The

video amplifier builds up the video signals and feeds them to the picture tube.

The sync generator at the transmitter keeps the entire video system in step as far as the sweeping of the electron beam at the transmitter and the receiver is concerned. As shown in figure 10-1, the sound system is separate from the video system. All power supplies, monitoring devices, and control circuits have been omitted in the block diagram in the interest of simplicity.

Before we go into the operation of the various circuits, there are certain important concepts that must be explained.

PICTURE ELEMENTS

If a picture printed from a photoengraving (for example, a halftone picture in a newspaper) is examined with a magnifying glass it will be seen to be composed of a large number of dots. The lightness or darkness of the picture is determined by the degree of coloration in the individual dot. Thus a halftone is made up of dots ranging from white to heavy black. The dots are the elements that make up the picture.

A television picture is formed in a similar manner. There is, however, one very important difference. In the picture made from the photoengraving, all of the elements of the picture are viewed simultaneously. In the television picture, the elements are presented one after the other in quick succession so that the observer sees the picture as a whole. The method of presenting picture elements in quick succession is called scanning and will be described after we have described the operating principles of some television camera tubes.

CAMERA TUBES

Figure 10-2 shows the structure of the iconoscope-type of picture tube. The image of the object is formed on the mosaic by the lens system. The mosaic is composed of many thousands of tiny isolated elements, thus allowing the picture to be analyzed into a fineness of detail that is limited only by the size of the individual islands and by the size of the scanning electron stream. The islands, or globules, are deposited on a sheet of mica, the back surface of which has a continuous metallic coating. Thus, each globule is capacitively coupled to the continuous metallic coating which serves as the signal electrode. When a scene is focused on the mosaic, the globules emit photoelectrons and charge up an amount proportional to the brightness of the picture elements. As the line scanning electron stream comes along, the electrons, having a velocity generated by approximately 1,000 volts, strike these globules and discharge them to an equilibrium voltage. The amount of discharge is proportional to the accumulated charge stored up since the previous electron scan. The discharge of the globules is capacitively coupled to the continuous metallic back plate. In this way the scanning beam produces a series of electrical signals from the globules in the mosaic, and one collecting electrode furnishes a connecting point for the lead to the video amplifier.

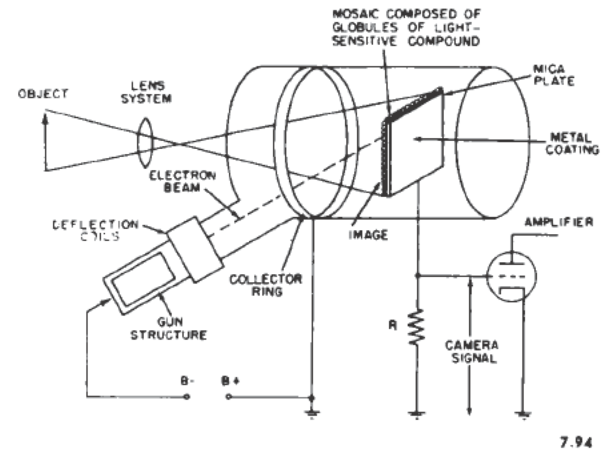

Figure 10-2.—Structure of a iconoscope.

The signal from the collecting electrode is about 1 millivolt and its frequency components may vary from 30 cycles per second to as high as several million cycles per second.

The iconoscope picture tube is now limited to motion picture work but will be found in some airborne TV equipment. In this tube both the scene to be transmitted and the electron stream are projected onto the same side of the photosensitive surface. Because the electron stream has an accelerating voltage of approximately 1,000 volts, considerable energy is present in the beam and much of the performance of the iconoscope depends upon secondary emission in charging and discharging the globules on the mosaic.

Image Orthicon

The image orthicon, figure 10-3, is an ultrasensitive television camera pickup tube that is used in modern conventional and closed circuit television systems. When this tube is used, a light image from the subject (arrow at extreme left) is picked up by the camera lens and focused on the light-sensitive face of the tube, releasing electrons from each of the thousands of tiny globules in proportion to the intensity of the light striking it. These electrons are directed on parallel courses from the back of the tube face to the target, from which each striking electron liberates several more electrons, leaving a pattern of proportionate positive charges on the front of the target. When the back of the target is scanned by the beam from the electron gun in the base of the tube, enough electrons are deposited at each point to neutralize the positive charges, the rest of the beam returning, as shown in figure 10-3, to a series of "electron multiplier" stages or dynodes, surrounding the gun. After the returning "signal" beam has been multiplied many times, the signal leaves the tube and is fed to the video amplifier.

The use of the image orthicon camera tube eliminates many of the difficulties encountered with the iconoscope. The image orthicon may be used for indoor or outdoor TV pickups. With this tube, scenes may be televised under light levels as low as 3 foot-candles illumination (ordinary room lighting); however, light levels of approximately 30 foot-candles provide results of broadcast quality. This is important in some Navy applications.

Vidicon Tube

The Vidicon camera pickup tube (fig. 10-4) has a transparent conductive coating, called the signal electrode, on the inner surface of the face plate; a layer of photoconductive material deposited on the signal electrode; an accelerating electrode; a focusing electrode; and a cathode emitter for producing a beam of electrons.

The beam of electrons is directed toward the layer of photoconductive material (on the cathode side of the signal electrode) at a low velocity because of the relatively low accelerating potential between the cathode and the accelerating electrode. A sharp beam is formed by the electrostatic field of the focus electrode and the axial magnetic field of the focus coil surrounding the tube. The electron beam is deflected by the deflection coil in such a way as to scan the photoconductive layer. When no light is permitted to reach this layer, its resistivity is extremely high. One side of the layer is maintained at cathode potential through contact with the scanning beam, and the other side is maintained at a small positive potential

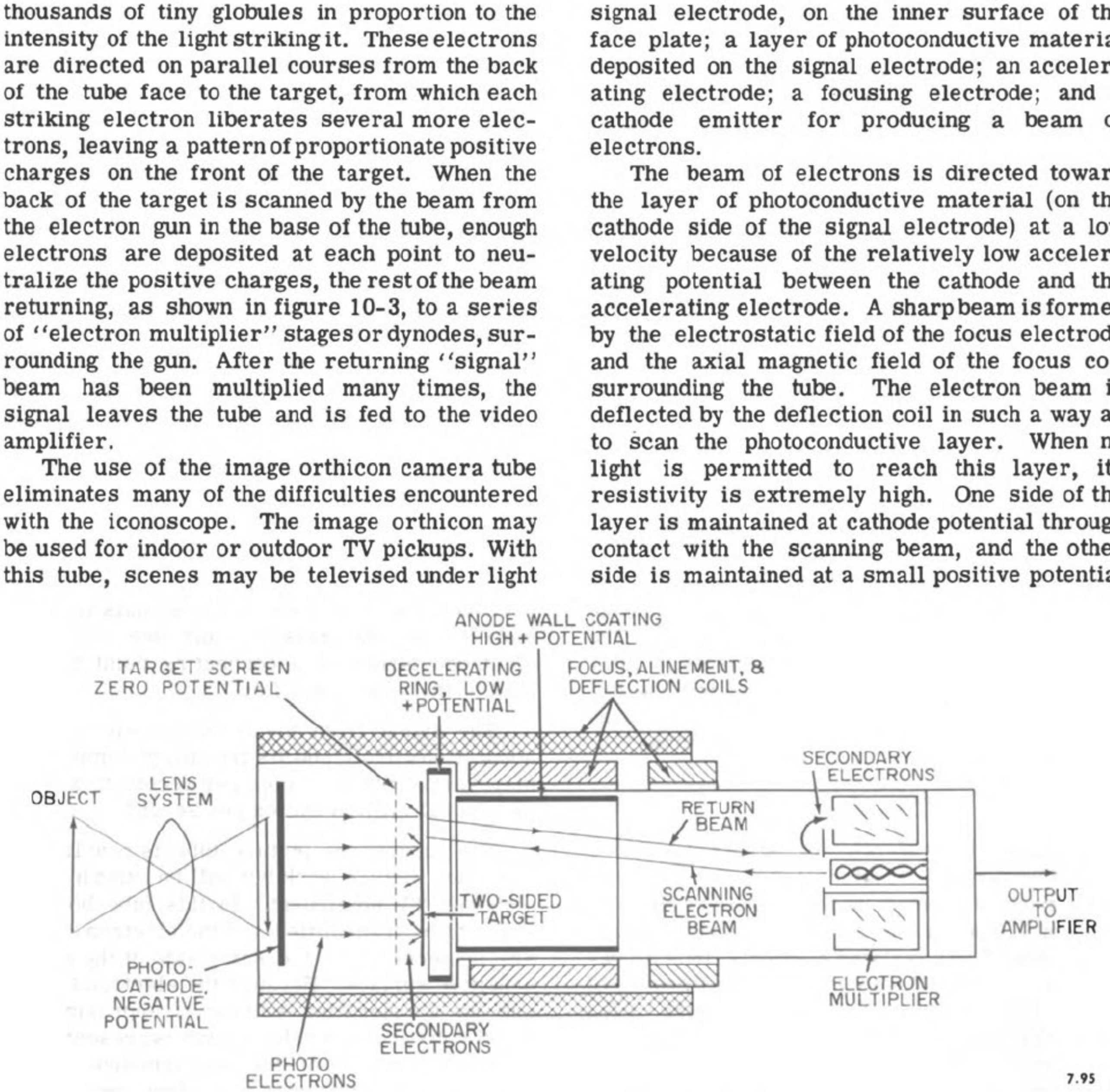

Figure 10-3.—Structure of image orthicon.

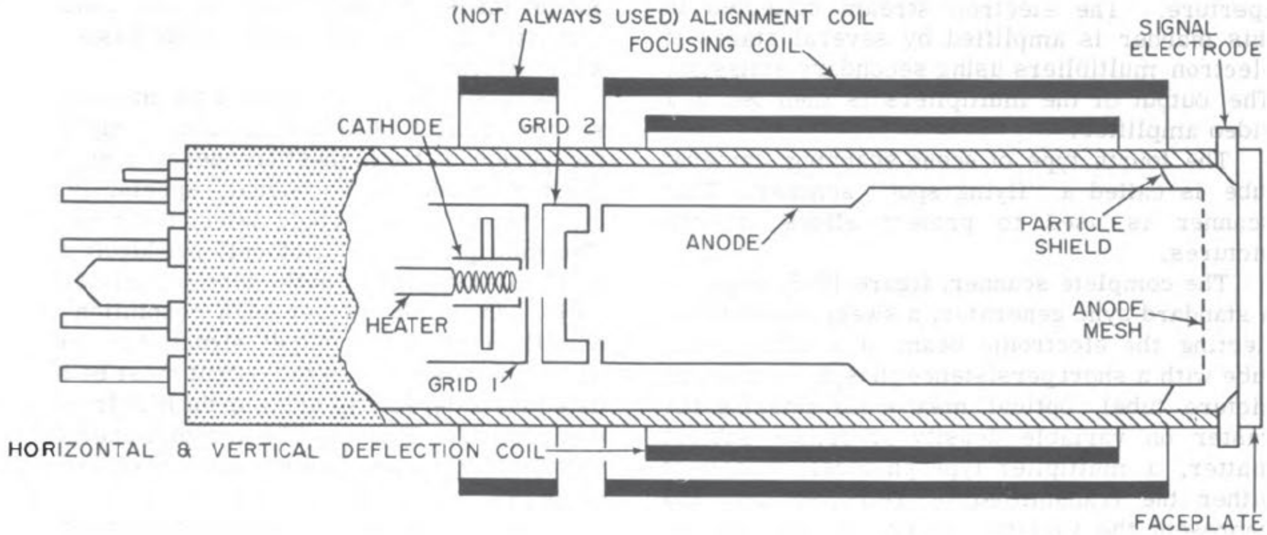

Figure 10-4.—Structure of vidicon tube.

of 15 to 50 volts by direct contact with the signal electrode.

When light from the scene being televised passes through the face plate and is focused onto the photoconductive layer, the resistivity of this material (which had been extremely high) is reduced in proportion to the amount of light reaching it. Because the potential gradient between adjacent elements of the photoconductive layer is much less than the potential gradient between opposite sides of the layer, electrons from the beam side of the layer leak by conduction to the other side between scans of the electron beam. Consequently, the potential of each element on the beam side approaches the potential of the signal electrode side and reaches a value that varies with the amount of light falling on the element. The electron beam on the next scan replaces just a sufficient number of electrons to each element to return it to the potential of the cathode. Because each element is effectively a small capacitor, a capacitive current is produced in the signal-electrode circuit that corresponds to the electrons deposited as the element is scanned. When these electrons flow through the load resistor in the signal-electrode circuit, a voltage, which becomes the video signal, is produced.

Associated with the Vidicon tube are the alinement coil, the focus coil, and the deflection coils. The alinement coil produces a magnetic field that is variable in both magnitude and direction and is used to adjust the direction of the electron beam so that it is parallel to the field of the focus coil. Control of the alinement coil current is accomplished in the camera-control unit (CCU).

The focus coil surrounds the Vidicon tube and establishes a magnetic field along the axis of the tube. It is connected between the +300 and the +150-volt power supplies through a resistor that is located in the rotatable section of the base unit.

The vertical and horizontal deflection coils are excited by linear sawtooth currents from the CCU. These currents produce the field that causes the beam to scan the photosensitive layer.

Other Camera Tubes

The third type of television camera tube in common use is called the "image dissector." In such a tube, the scene is focused upon a continuous photosensitive surface (such as a film), and the resulting photo emission is focused as a pattern by suitable focusing fields and accelerated toward a small collecting aperture. The whole photoelectric pattern of streaming electrons is then deflected in a scanning process, so that individual areas of the picture are successively brought to impinge upon the small

aperture. The electron stream collected in this manner is amplified by several stages of electron multipliers using secondary emission. The output of the multipliers is then fed to a video amplifier.

The fourth type of scene scanning (camera) tube is called a ''flying spot'' scanner. This scanner is used to project slides or still pictures.

The complete scanner, figure 10-5, requires a standard sync generator, a sweep unit for deflecting the electronic beam of a cathode-ray tube with a short persistence phosphor (ordinary picture tube), optical means for imaging the raster on variable density or opaque subject matter, a multiplier type photocell to collect either the transmitted or reflected light and represent the variable density or variable reflection as an instantaneous voltage variation with time, and suitable mixing circuits to provide composite video output. The raster traced

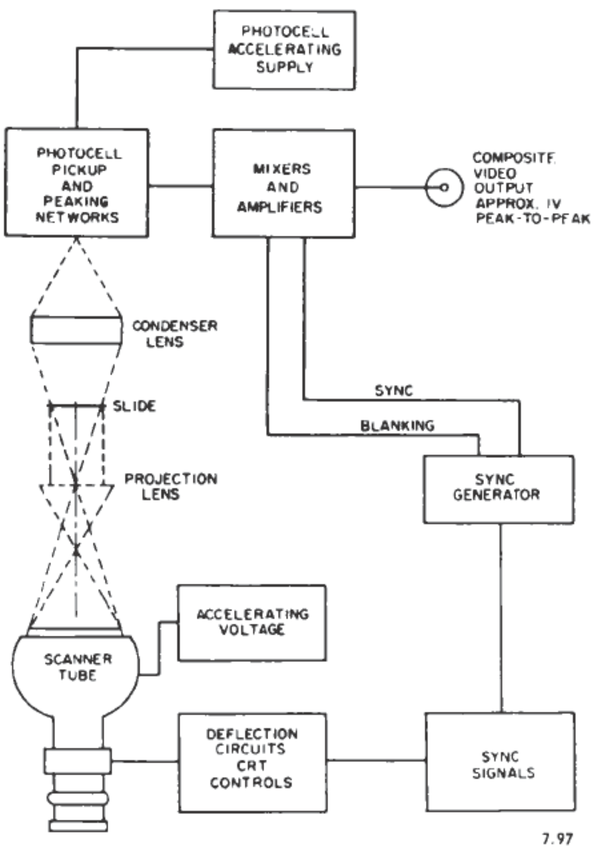

Figure 10-5.—Slide scanner using flying spot scanner cathode-ray tube.

out on the short persistence screen results in a moving light source which is the basis of the whole operation.

Because the decay time of the moving point source of light is relatively long compared to the period of the highest frequency components desired in the video signal, special peaking circuits (to be described later) must be used. The multiplier-type photocell produces a high level output signal with good signal-to-noise ratio. In order to get high resolution (good detail) in the video output signal, the low frequency components in the output must be attenuated considerably to bring up the high frequency components. This may be accomplished either with selective amplifiers, with R-C or R-L networks.

When a slide is to be transmitted, the raster traced out on the cathode-ray tube is imaged optically on the slide to be reproduced. Condenser lenses are used past this focal plane to collect the maximum light energy passing through the slide, and converge this energy to the aperture dimensions of the multiplier photocell.

SCANNING

As mentioned previously, the television image is transmitted element by element in quick succession. To transmit images in this manner, it is necessary to employ a system of scanning; that is, the image is swept by an electron beam in a systematic manner so that during a period of time all parts of the image are swept by the electron beam. Likewise, in the receiver, where the image is reconstructed, a similar system of scanning is employed.

The principle of scanning can be illustrated by the following example. Assume that you have a flashlight that can produce a very narrow beam of light and that you wish to view a picture on the wall of a dark room. Obviously, because of the narrow beam, you must view a portion of the picture at a time. If you can manipulate the light very fast, you can view the picture in the same manner as the picture would be produced in television. To do this you would start at the upper left hand corner of the picture and move the beam rapidly to the right along the top of the picture. When the right-hand edge of the picture is reached, turn off the beam and swing it rapidly to the left and one spot width lower. Turn the light on and again sweep it rapidly to

the right. Each sweep of the light is a scan line and in commercial television there are 525 lines to a picture. Thus, when you reach the bottom right-hand corner of the picture you have completed a frame and the light is turned off and moved to the upper left-hand corner of the picture to start the scanning process over again.

In camera tubes, an electron beam of small diameter is formed and given the desired velocity by the electron gun located in the neck of the tube. Deflection (sweeping) of the electron beam across the mosaic is accomplished by the deflection coils that are positioned around the neck of the tube.

A simplified illustration of scanning is shown in figure 10-6. The electron beam begins its scan at the upper left-hand corner of the mosaic and moves horizontally along line 1 toward the right. The globules shown are exaggerated in size to simplify the illustration. All of the globules in line 1 are in the bright part of the mosaic. Therefore, they have lost the same number of electrons and accumulated uniform positive charges. As the beam sweeps across these globules, the charges are neutralized, and a relatively steady current flows from the metal coating of the mosaic plate down through R (fig. 10-6), through the B supply to the electron

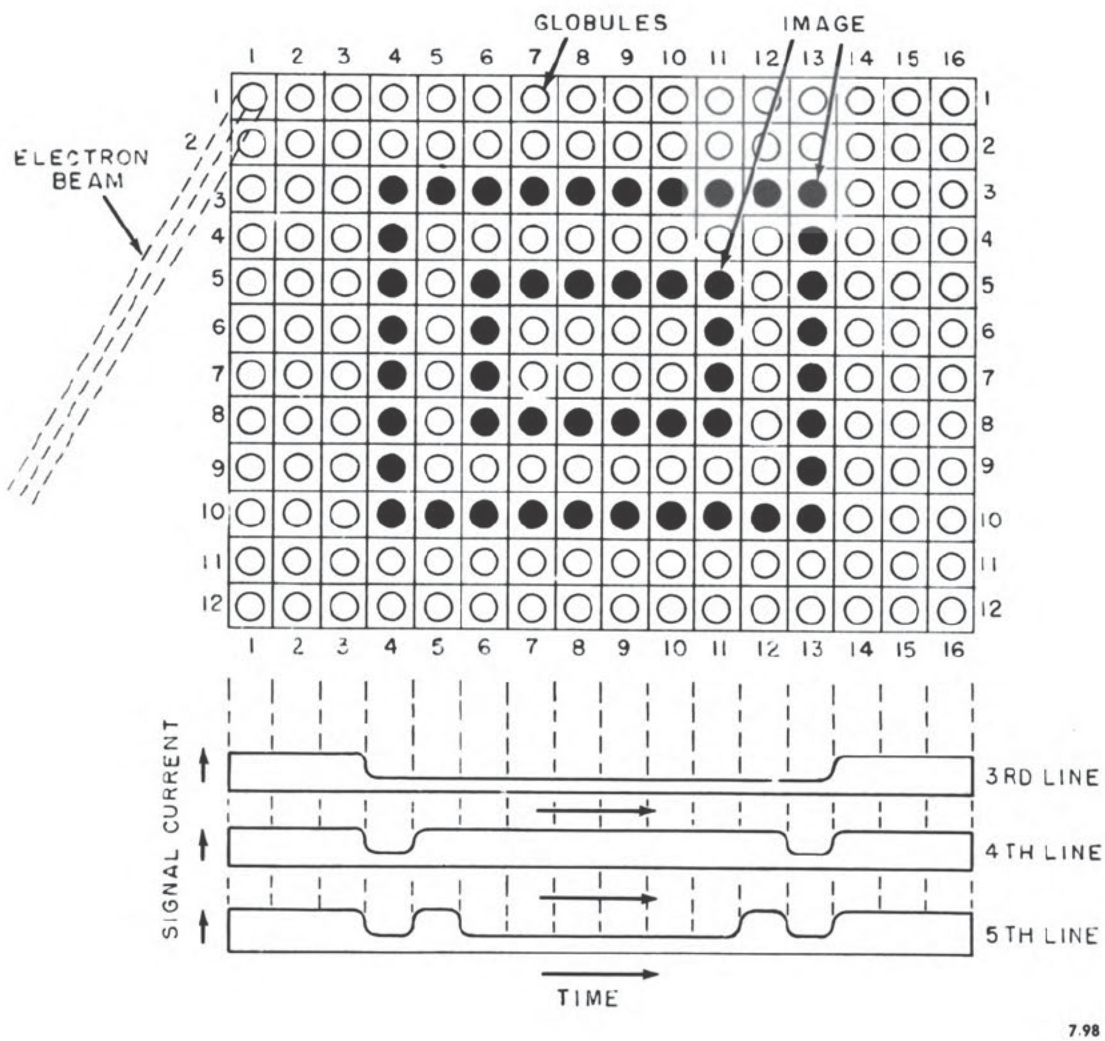

Figure 10-6.—Simplified illustration of scanning.

beam and back to the associated globules. The same situation prevails while line 2 is being scanned.

A part of the image is located in line 3, and there will not be a steady flow of current through R as the beam traverses this line. The current flow is steady until the fourth globule is reached. From 4 through 13 the globules have been charged slightly, and the discharge current through R is less when the beam sweeps across the black globules. Beginning with globule 14, the output current increases again. In line 4 the current through R is steady until the beam reaches globule 4, then decreases until the beam reaches globule 5. The current through R then increases and remains steady until the beam reaches globule 13. The current then decreases while the beam is on globule 13 and increases when the beam strikes globule 14. The current through R then remains steady through the rest of line 4.

When the electron beam scans line 5, the current through R is steady while the beam scans globules 1, 2, and 3; decreases for globule 4; comes back to the steady value for globule 5; decreases for globules 6 through 11; goes to the steady value for globule 12; decreases for globule 13; and then returns to the steady value for the rest of line 5. The relative strength of the signal currents are shown at the bottom of figure 10-6.

In a practical camera tube, the globules are extremely small and close together, so the picture will have great detail. Therefore, there will be many changes in current during the course of a single scan. The flow of the tiny pulses of current through R (fig. 10-2) develops signal voltages at the input of the video amplifier. In order that all of these signal voltages may be passed through the amplifier, it must be capable of passing a wide band of frequencies.

BAND-PASS REQUIREMENTS

When we speak of the band-pass requirements of an amplifier we are referring to the range of frequencies which must pass through the amplifier. For code work where only one frequency is concerned, a very narrow band-pass (as low as 100 cycles) is used. The band-pass required for television is much greater and some idea of these requirements may be gained from the following explanation.

Assume that each line to be scanned contains 1000 globules, each insulated from the others; it is assumed also that the diameter of the electron beam is approximately that of a globule and that each adjacent globule has a different charge.

In standard United States home television, 525 lines are scanned by the electron beam in tracing over the entire mosaic surface of the camera tube. As will be shown later, some of these lines are lost during the retrace (blanking) time. The surface of the mosaic is completely scanned 30 times in 1 second. Therefore, the number of lines scanned in 1 second is 525 x 30 = 15,750; this is called the HORIZONTAL SWEEP FREQUENCY.

The number of globules (each having a charge equivalent to a picture element) contained in 1 line is assumed to be 1000. Therefore, the number of picture elements in the image each second is 15,750 x 1000 = 15,750,000.

If a complete cycle is assumed to be the change in signal voltage developed when the beam passes across 2 successive globules, then the frequency is 15,750,000 / 2 = 7,875,000 cps. In order to reproduce all of the picture elements perfectly, the transmitter and receiver circuits must be able to pass, without distortion, a band of frequencies approximately 7.87 mc wide.

In actual practice, it is not necessary to pass a band of frequencies this wide. There are less than 1000 picture elements per line, and each globule of the light-sensitive compound may not be charged differently from its neighbor. These and other considerations permit a band-pass of 4 mc to give satisfactory results.

Assume that a band-pass of 4 mc is all that is possible. How much HORIZONTAL DETAIL (bits of picture detail on a horizontal line) is then possible? The period of a 4 mc signal is 0.25 μs, which is the time required by the electron beam to scan across 2 adjacent elements. Because 15,750 lines are scanned in 1 second, the period of 1 line is 63.5 μs. From this, the time used during the retrace (10.2 μs) must be subtracted to give the actual period of 1 line. The period of 1 line is then 53.3 μs, and the number of cycles per line is 53.3 / 0.25 = 213 (approx.). The number of elements per line is therefore approximately 2 x 213 = 426.

VERTICAL DETAIL depends on the number of horizontal lines scanned per picture frame. This may be illustrated by the use of figure 10-5. Assume that in line 3 each black dot

(picture element) is divided into 2 dots and placed one above the other within the confines of line 3. When the beam scans the line, both dots will be covered simultaneously and only one signal will be available at the output. If the beam width is made smaller and twice as many lines are scanned, a signal will be produced from both black dots; that is, the vertical detail will be improved.

In the complete scan of one picture frame many lines are lost during flyback time. These lines are therefore not effective in producing vertical detail. It may be assumed that there are 380 horizontal lines that are effective in producing vertical detail. The number of picture elements per frame is 426 x 380 = 161,880; and at 30 frames per second, the total number of cycles produced is 161,880 x 30 = 4,856,400.

As previously stated, a band pass of 4 mc will give reasonably satisfactory results.

FLICKER

The eye retains an image for a fraction of a second (about 1/15 second) after the image is formed on the retina. This characteristic of the eye is utilized in moving pictures and television. Actually, it is because of this characteristic that it is possible to have moving pictures or television.

Moving-picture films are composed of a series of individual pictures (frames) that are shown on the screen in quick succession. The illusion of motion comes about because the figures may be displaced slightly in succeeding frames; and if enough frames are shown per second, the figures appear to move because of the rapid sequence of the frames and the persistance of vision. At approximately 15 frames per second the motion appears continuous, but there is a pronounced flicker. At 24 frames per second, some flicker is present; however, it is much less objectionable than at 15 frames per second. To further reduce the flicker, a special shutter arrangement is used. The shutter cuts off the light from the screen while a new frame is moved into position. It also cuts off the light from the screen once more while the picture frame is stationary. Thus the shutter divides the presentation of every frame into two equal time intervals. This has essentially the same effect as increasing the frame frequency to 48 frames per second.

In television, similar problems are encountered. To keep flicker from becoming objectionable, 30 complete frames per second are shown. Flicker is further reduced by the use of interlaced scanning, which has essentially the same effect as increasing the frame frequency to 60 frames per second. The horizontal scanning speed, and band-pass requirements of the composite TV signal remain the same.

Interlaced scanning is illustrated in figure 10-7. As has been mentioned before, band-pass considerations, the problems of synchronization, and the necessity for detail lead to the choice of 525 horizontal scanning lines per frame. To reduce flicker by means of interlaced scanning, the electron beam scans the odd-numbered lines first and then the even-numbered lines. Thus, two scans (FIELDS) are necessary to complete one FRAME. For example, as shown in figure 10-7, the sweep for the first field begins on the left side of line 1. The beam moves across the image plate at a slight downward angle (pulled downward by the vertical deflection coils). At the end of the line, the electron beam is blanked out during the retrace to the left side of line 3. This process is continued until the middle of line 525 is reached (only 25 lines are shown in the figure). Therefore, 262.5 lines are scanned in the first field. When the beam reaches the middle of the last line, it is blanked out and returned to the middle of line 2 where the trace for the second field starts. The even-numbered lines are scanned in sequence until the end of line 524 is reached. At that instant the beam is blanked out and returned to the beginning of line 1, and the whole process is repeated.

In order to keep the movement of the electron beams in both the camera and picture tubes in step, and in order to blank out the signals from the picture tube during the horizontal and vertical retrace periods, synchronizing (sync signals) and blanking signals are sent out by the transmitter.

SYNCHRONIZING AND BLANKING SIGNALS

Blanking signals (voltages) are used in both the camera tube and the picture tube control circuits to cut off the electron beam at the end of a horizontal scan line so that the return

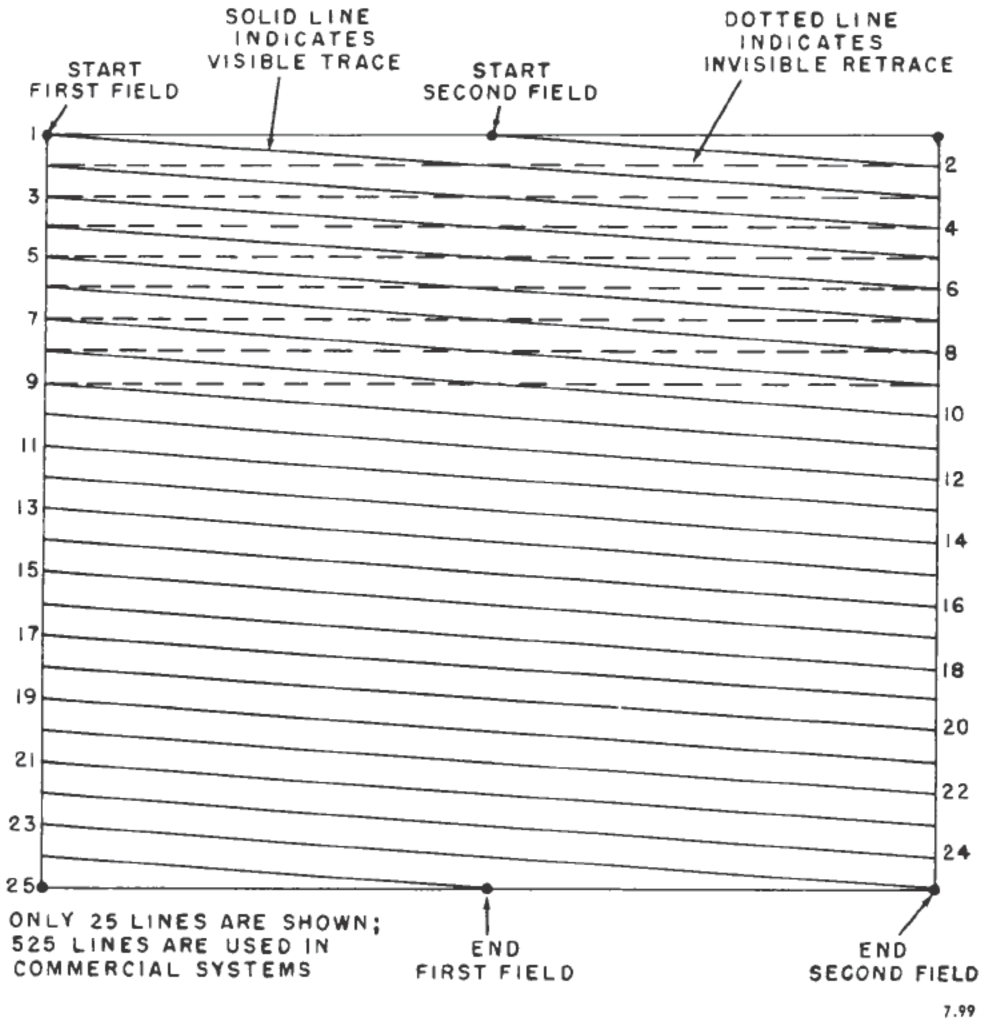

Figure 10-7.—Interlaced scanning.

trace will not be active in producing picture signals at the transmitter or picture elements at the receiver. Blanking signals are also used to blank out the vertical return trace following the scan of each field.

Included with the blanking voltages (actually superimposed on them) are the synchronizing pulses that trigger the horizontal and vertical sweeps in the camera tube and the picture tube. One set of pulses, called the HORIZONTAL SYNC PULSES, triggers the horizontal sweep at the correct instant 15,750 times a second. Another set of pulses, called the VERTICAL SYNC PULSES, trigger the vertical sweep at the correct instant 60 times a second.

For the horizontal scan, the sequence is as follows: (1) the signal is blanked out when the trace reaches the right-hand side of the screen; (2) an instant later the horizontal sync pulse arrives and brings the trace to the left-hand side of the screen; (3) the next horizontal trace begins; and (4) an instant later the blanking pulse is removed and the trace is visible until it reaches the right-hand side of the screen.

For the vertical scan, the sequence is as follows: (1) the signal is blanked out at the end of the first field (at the end of line 262.5); (2) the vertical sync pulse arrives and brings the trace to the middle of line 2 at the top of the screen; (3) the next vertical sweep begins; and (4) the blanking signal is removed. During the second field, the lines missed on the first field are filled in.

In order to keep the horizontal sweep locked in step during the vertical retrace period and in order to produce interlaced scanning, the vertical sync pulses have a special serrated form and are preceded and followed by equalizing pulses. The composite video signal (the complete signal, including video and sync pulses), particularly the vertical and horizontal sync pulses, will have more meaning when the method of separating the pulses is described later in the chapter.

All television receivers must perform essentially the same functions. They must be able to select the desired carrier frequency, amplify the required band of frequencies, separate and demodulate the video and audio frequencies, separate and utilize the sync pulses, and finally reproduce the picture on the screen, and the sound at the loudspeaker. How well each of these jobs is accomplished depends, in a large measure, on the design and the quality of the TV receiver.

As mentioned previously, closed circuit TV does not ordinarily use audio. Because the signal is sent from the camera unit to the viewing unit via cables, there are no antenna problems. However, where the camera unit contains a small oscillator which furnishes an amplitude modulated video signal, the viewing unit must have a tunable receiver.

CLOSED CIRCUIT TV SYSTEMS

A comparison of standard and closed circuit TV systems is shown in figure 10-8. Figure 10-1 has been simplified here so that differences in the systems will be readily apparent.

One closed circuit TV system used by the Navy is shown in figure 10-8,B. This system can be compared to the "wireless" record

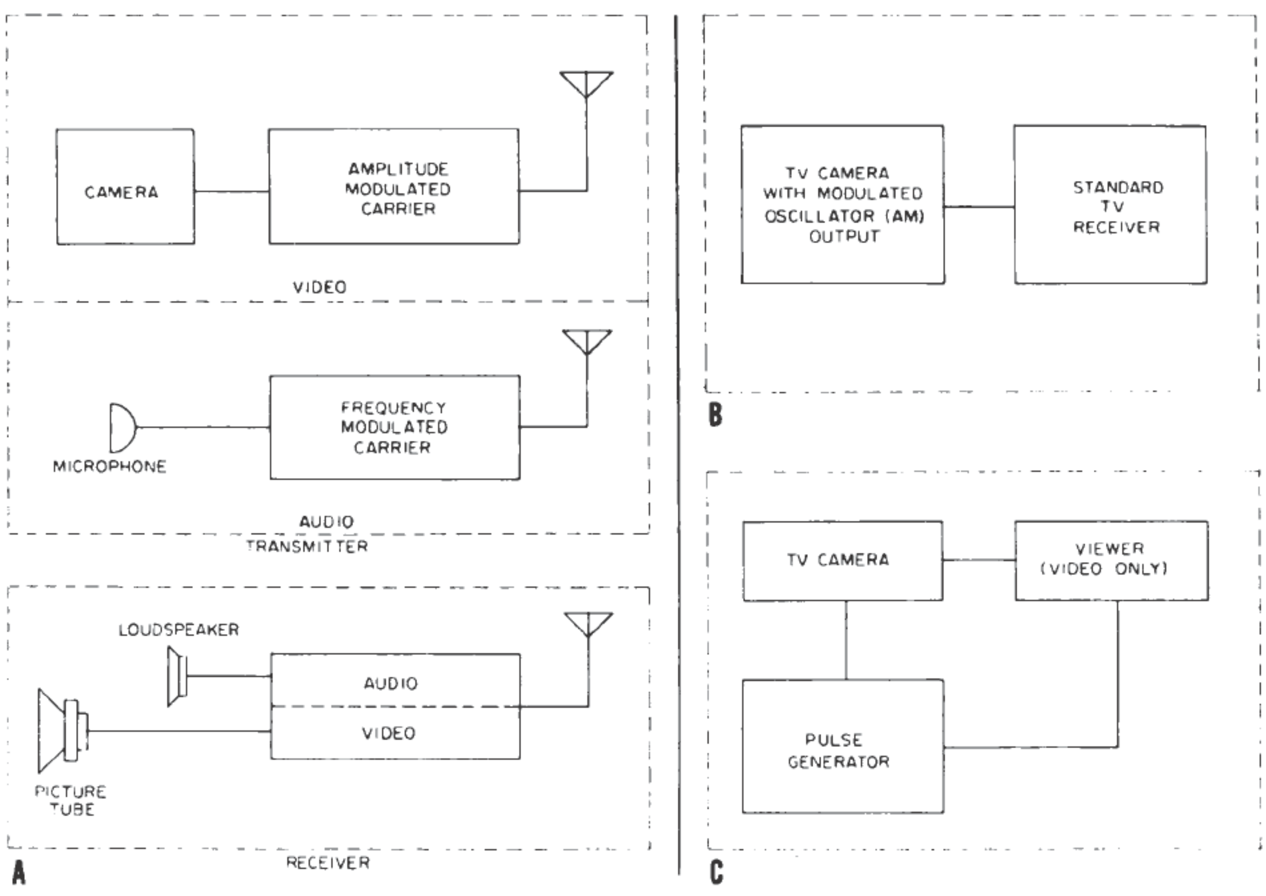

Figure 10-8.—Comparison of standard and closed circuit TV systems.

players used to reproduce records through a radio set without a direct connection between units. The closed circuit TV system does, however, have a direct connection between units.

The output of the camera is used to amplitude modulate a low powered oscillator that can be tuned to any channel frequency of a standard home TV receiver. The modulated output of this oscillator is fed, via coaxial cable, to one or more TV sets. In this system, the TV camera contains its own power supply, sweep and sync generators, and a video amplifier chain. The receiver is a standard home TV set. No provision has been made to transfer audio signals between the camera site and the viewing location. However, should this become necessary, it would be possible to feed the output of a microphone into a small preamplifier and then feed the preamplifier output, via coaxial cable, to the audio section of the TV set being used as a viewer.

Figure 10-8,C, is a block diagram of a more sophisticated system that has been specially designed for closed circuit TV applications. A separate cabinet houses a master oscillator which is used as a primary frequency source to control all sweep and pulse circuits in both the camera and viewer. The viewer replaces the receiver in the system shown in figure 10-8,B, and contains no audio section, and no front end tuner and mixer section. Because there is no conversion, there is no i-f section. The output of the camera is fed directly to the video amplifier in the viewer via cables.

The viewer has a 21-inch picture tube and instead of the standard 525-line picture, uses and 875-line picture for greater detail. Several viewers can be connected to one camera so that events taking place at one location can be viewed simultaneously at several locations.

Several components are common to all TV systems; a short discussion of each follows.

VIDEO DETECTORS

The video detector in a television receiver performs essentially the same function as the second detector in a superheterodyne amplitude-modulated radio receiver. It rectifies the signal (video and sync pulses) fed to it by the video system. In figure 10-8,B, the signal fed to the video detector would be the video i-f system components and the detector would remove the i-f components, and feed the remaining signal and sync information to the video amplifier. In the signal from the camera in figure 10-8,C, there are no i-f components because the video pulses are fed directly from the camera to the viewer. Various video detector circuit arrangements, employing either diode electron tubes or crystals, are used by the manufacturers of TV sets.

One type of diode detector is shown in figure 10-9,A. Two methods of connecting the detector are shown. In part (1) the output has a negative picture phase, and in part (2) it has a positive picture phase.

In figure 10-9,A (1), the negative-going (less positive) picture signals correspond to the brighter portions of the picture and the higher amplitudes (in a positive direction) correspond to progressively darker portions of the picture. This corresponds to the negative picture phase.

In figure 10-9,A (2), the positive-going (less negative) picture signals correspond to the brighter portions of the picture and the higher amplitudes in a negative direction correspond to progressively darker portions of the picture. This corresponds to the positive picture phase.

The concept of negative picture phase may be made clearer from the following considerations. A video signal having a negative picture phase, figure 10-9,A (1) will cause the cathode of the picture tube to be driven in a positive direction beyond cutoff during the blanking pulses. During the darker portions of the picture the cathode will be driven considerably in the positive direction, but not to cutoff. Consequently, a few electrons will reach the picture tube screen, and the screen will be relatively dark. During the brighter portions of the picture the cathode will be driven only slightly in the positive direction, and many electrons will reach the picture tube screen. The screen will therefore be relatively bright.

The concept of positive picture phase may be made clearer from the following considerations. A video signal having a positive picture phase will cause the grid of the picture tube to be driven negative below cutoff during the blanking pulses, figure 10-9,A (2). During the darker portions of the picture the grid will be driven considerably negative, but not to cutoff. Consequently, fewer electrons will reach the picture tube screen, and the screen will be

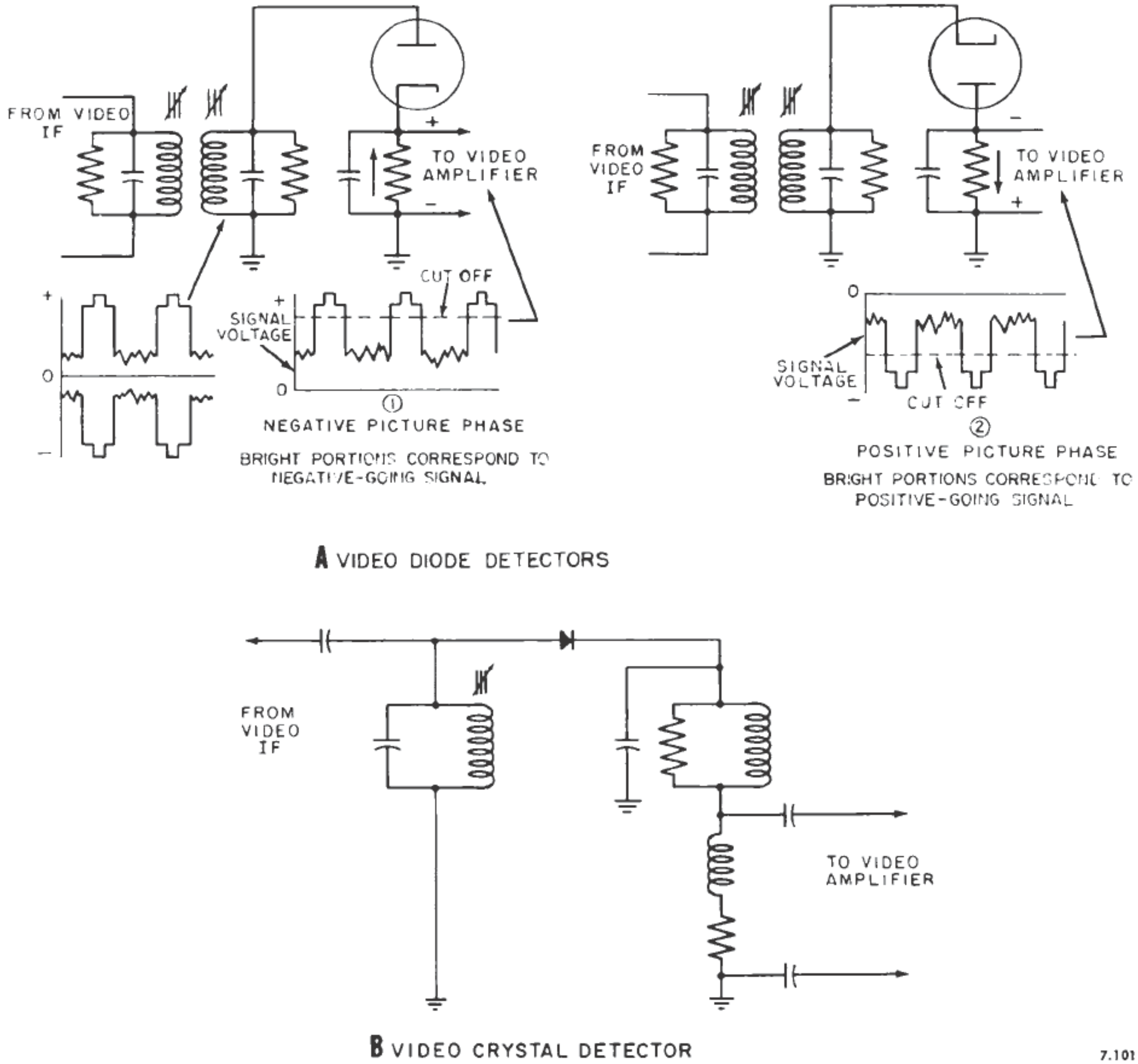

Figure 10-9.—Video detectors.

relatively dark. During the brighter portions of the picture the grid will be driven only slightly negative, and many electrons will reach the picture tube screen. The screen will therefore be relatively bright.

In the United States, negative transmission is used; that is, the television signal is transmitted with the negative picture phase. In certain other countries, positive picture transmission is used.

The output of the detector in the receiver may have a positive or a negative picture phase as indicated in figure 10-9,A (1) and (2), irrespective of the type of transmission used. In either case, the video amplifiers must supply a signal having a positive picture phase to the grid of the picture tube. If the signal is applied to the cathode of the picture tube, it must have a negative picture phase.

The strength of the signal at the output of the detector is not sufficient to drive the picture tube, therefore, one or more stages of video amplification are necessary.

The circuit arrangement of a video crystal detector is shown in figure 10-9,B. The crystal performs essentially the same function as the diode tubes.

VIDEO AMPLIFIERS AND D-C RESTORERS

After the video signal (containing the video information and the blanking and sync pulses) has been rectified in the second detector, it must be amplified in one or more video amplifiers before it is applied to the picture tube. Because a wide band of frequencies must be passed without discrimination by the video amplifiers, they must be carefully designed. Special high- and low-frequency compensating circuits must be used to extend the approximate range of frequencies passed from 30 cycles to 4 mc. In other words, FREQUENCY DISTORTION must be eliminated as much as possible.

The low-frequency video components include the low-frequency a-c variations (represented on the picture screen as portions of the image that do not contain fine detail), the blanking pulses, and the sync pulses (vertical and horizontal). The high-frequency video components are the high-frequency a-c variations that produce the fine detail on the picture screen. In addition to the low-frequency and the high-frequency components in the transmitted signal, there is a zero frequency, or d-c component, present.

If all of the frequency components are not properly amplified in the video amplifier section, a distorted image will be produced. The distortion may appear as a lack of fine detail, a lack of image sharpness in the larger objects, or a lack of contrast.

In addition to frequency distortion, PHASE DISTORTION must also be eliminated as much as possible. In effect, phase distortion means that certain components (frequencies) that make up complex waveforms are not passed by the amplifier in the same length of time that other frequencies are passed. For example, in resistance-coupled amplifiers the coupling capacitor and the grid resistor, acting together, cause a phase shift that varies with the frequency.

Phase distortion may alter the background of the picture shown on the television screen; portions that should be white may be gray or even black. At the lower frequencies, excessive phase shift may cause large objects to be blurred on the screen. At the higher frequencies, excessive phase shift causes the fine detail to be blurred.

ELIMINATING FREQUENCY AND PHASE DISTORTION

The average resistance-coupled amplifier has a flat response of only a few thousand cycles per second and is therefore not suitable for amplifying video frequencies.

In order to amplify the higher frequencies as much as the middle range of frequencies, it is necessary to use some form of HIGH-FREQUENCY COMPENSATION. This type of compensation commonly takes the form of SHUNT COMPENSATION or SERIES COMPENSATION or a combination of both.

In a resistance-coupled amplifier the output capacitance of the first amplifier stage, the distributed capacitance of the wiring, and the input capacitance of the second amplifier stage tend to shunt the high frequencies of the first stage to ground, thereby leaving less output voltage at these frequencies available to the second stage. The high frequencies are therefore not amplified as much as the middle range of frequencies.

This shunting effect may be compensated for (or the frequency range extended) by the use of a small inductor inserted in series with the plate load. The value of this inductor is so chosen that it will neutralize the distributed (output) and input capacitance of the circuit. That is, this inductor is so chosen that it, together with the distributed (output) and input capacitance, will form a parallel resonance circuit that is resonant at a frequency where the response curve begins to fall appreciably. The frequency range is thereby extended. This type of compensation is called shunt compensation, and the coils are called PEAKING COILS.

Series compensation may also be used. In this case, a small inductor is added in series with the coupling capacitor and forms a series resonant circuit (resonant at a frequency where the response curve begins to droop) with the distributed (output) and input capacitances. At

resonance, increased current will flow through these capacitances, and larger voltages will be available at the input of the amplifier tube. To prevent a sharp peak in the response curve, a resistor is shunted across the series inductor.

In order to amplify the lower frequencies as much as the middle or high range of frequencies, it is necessary to use some form of low-frequency compensation. At low frequencies, the reactance of the coupling capacitor is large and much of the signal voltage is dropped here and is not available at the grid input. A large coupling capacitor could be used, but if this were done, the stray capacitance and leakage current would be increased. Of course, a coupling capacitor introduces some phase shift at low frequencies.

Both the loss in gain and the increase in phase shift at the lower frequencies may be compensated for in part by dividing the load resistor into two parts and bypassing one part with a capacitor. At the lower frequencies the plate load includes both resistors, and therefore the output voltage is higher. At the higher frequencies a portion of the load is effectively bypassed by the capacitor, and the output is proportionately lower.

D-C RESTORERS

The d-c restorer (or clamper) restores the d-c component of a pulse waveform after this component has been removed by the passage of the waveform through the coupling capacitor in the video amplifier stage. It is necessary to reinsert the correct d-c component at the input of the television picture tube if the correct level of background illumination is to be maintained. Also, if the correct d-c component is not reinserted, the blanking level will vary (instead of remaining constant, as it should), and retrace lines will appear on the screen during the time the blanking voltage is insufficient to cut off the picture tube during retrace.

The average brightness of one scanned line may differ widely from the average brightness of another scanned line, as indicated in figure 10-10,A.

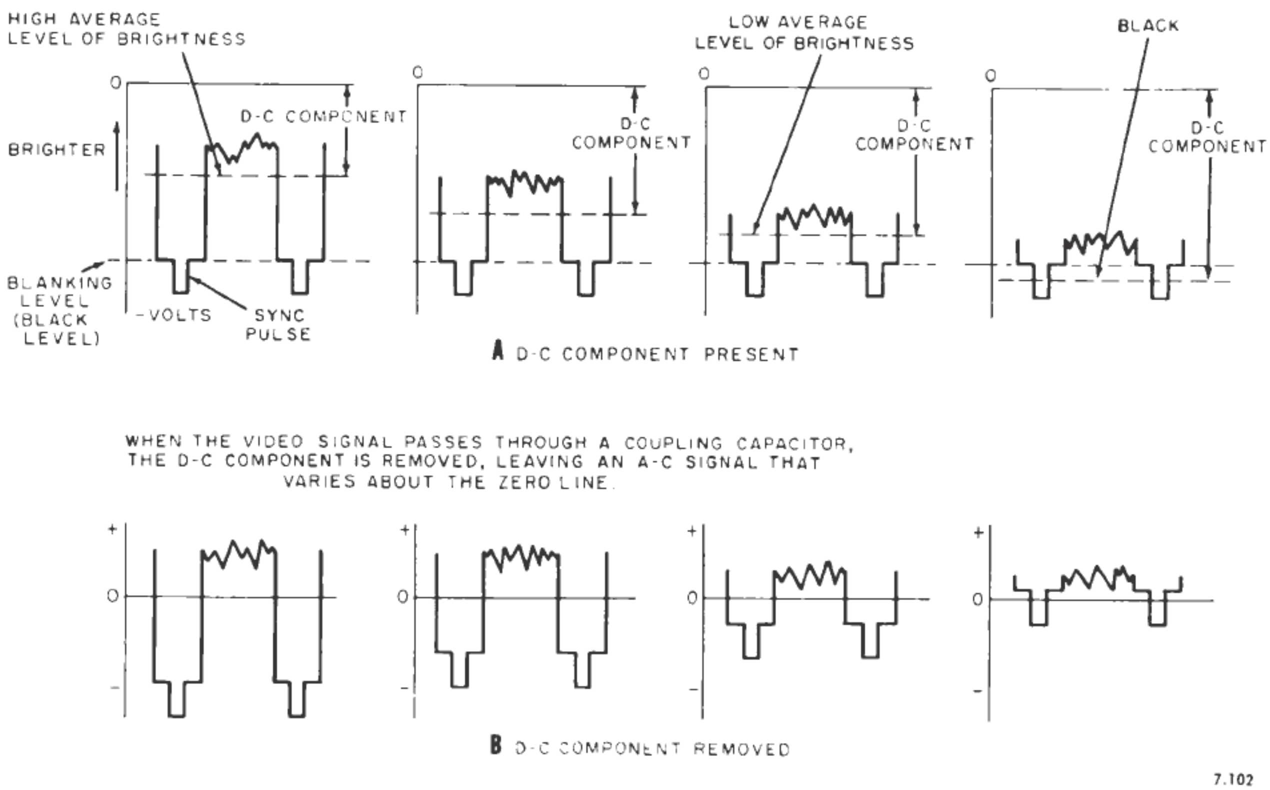

Figure 10-10.—Function of the d-c component in the video signal.

The average d-c component depends on the average brightness of a line. A low d-c component in the negative direction means that there exists a high level of brightness during that line; a high d-c component in the negative direction means that there exists a low level of brightness during that line. The average d-c component therefore, establishes the blanking level.

Figure 10-10,B, illustrates what happens when the d-c component is removed by the passage of the video signal through a coupling capacitor. Although the picture tube may be biased so that it will not be driven in a positive direction beyond a certain value, nevertheless the blanking level will vary and the retrace will often be visible. The background brightness level will also differ from that at the transmitter.

Simplified circuits of two types of d-c restorers are shown in figure 10-11. The function in each case is to restore the d-c component that was lost when the video signal passed through the coupling capacitor of the video amplifier. D-c restoration is accomplished by adding to the instantaneous a-c signal enough d-c voltage to bring the blanking voltage to the cutoff point.

The action of the diode restorer shown in figure 10-11,A, may be explained in the following manner. Without the diode the input signal voltage has the appearance of that shown in figure 10-10,B. During the negative portion of the cycle (when the blanking and synchronizing pulses are active) the diode conducts because its cathode is negative and its plate is positive. This action occurs because the self-induced voltage across L opposes the B supply voltage and exceeds the value between point B and ground. Capacitor C charges rapidly through the diode and has the polarity indicated. The amount of the charge (voltage across C) depends on the strength of the input signal.

During the positive portion of the signal, shown above the 0 line in figure 10-10,B, the tube cannot conduct, and C discharges relatively slowly through R. A positive potential, which reduces the bias on the picture tube, is thus applied between grid and cathode during the scan interval between the blanking pulses. During this interval the diode is effectively an open circuit, and the video signal appears across R in series with the d-c voltage supplied by C. The greater the input voltage, the less will be the net bias remaining on the grid of the picture tube, and the higher will be the average brightness. Thus the condition existing in figure 10-10,A, is reestablished.

A grid-leak d-c restorer circuit is shown in figure 10-11,B. The incoming video signal has a negative picture phase, and the d-c component is missing; the output video signal has a positive picture phase, and the d-c component is restored, or reinserted.

The action of the grid leak may be explained simply. There is no fixed bias on the tube, and the grid goes positive whenever a positive pulse is applied. Grid current flows, and C charges rapidly through the conducting grid circuit. If a large pulse is applied, a large amount of grid current flows and a large bias is developed. If a small pulse is applied, a small amount of grid current flows and a small bias is developed. These two actions tend to stabilize the plate current at the same level during the pulses of current. That is, the blanking pulses are lined up at the same level as they were before the d-c component was removed. During the interval between blanking pulses, C discharges slowly through Rg.

It should be emphasized that the bias remains essentially constant (because of the long time constant of C and Rg) during the interval between blanking pulses. If this were not true, the d-c component would be lost.

SYNCHRONIZING CIRCUITS

So far the discussion of circuits has focused primarily on delivering the video signal to the picture tube. Equally important, from the point of view of overall receiver operation, is the system by which the various circuits are synchronized with those at the transmitter and made to function together to produce the desired picture. As has been stated before, the blanking pulses and the horizontal and vertical synchronizing (sync) pulses are amplified in the various stages along with the video information. The video signals and the blanking pulses are applied either to the grid or to the cathode of the picture tube. However, the sync signals are removed from the composite video signal (generally in the last video stage) and applied to the horizontal and vertical sync circuits. In some instances the d-c restorer circuit is modified to serve also as a sync clipper.

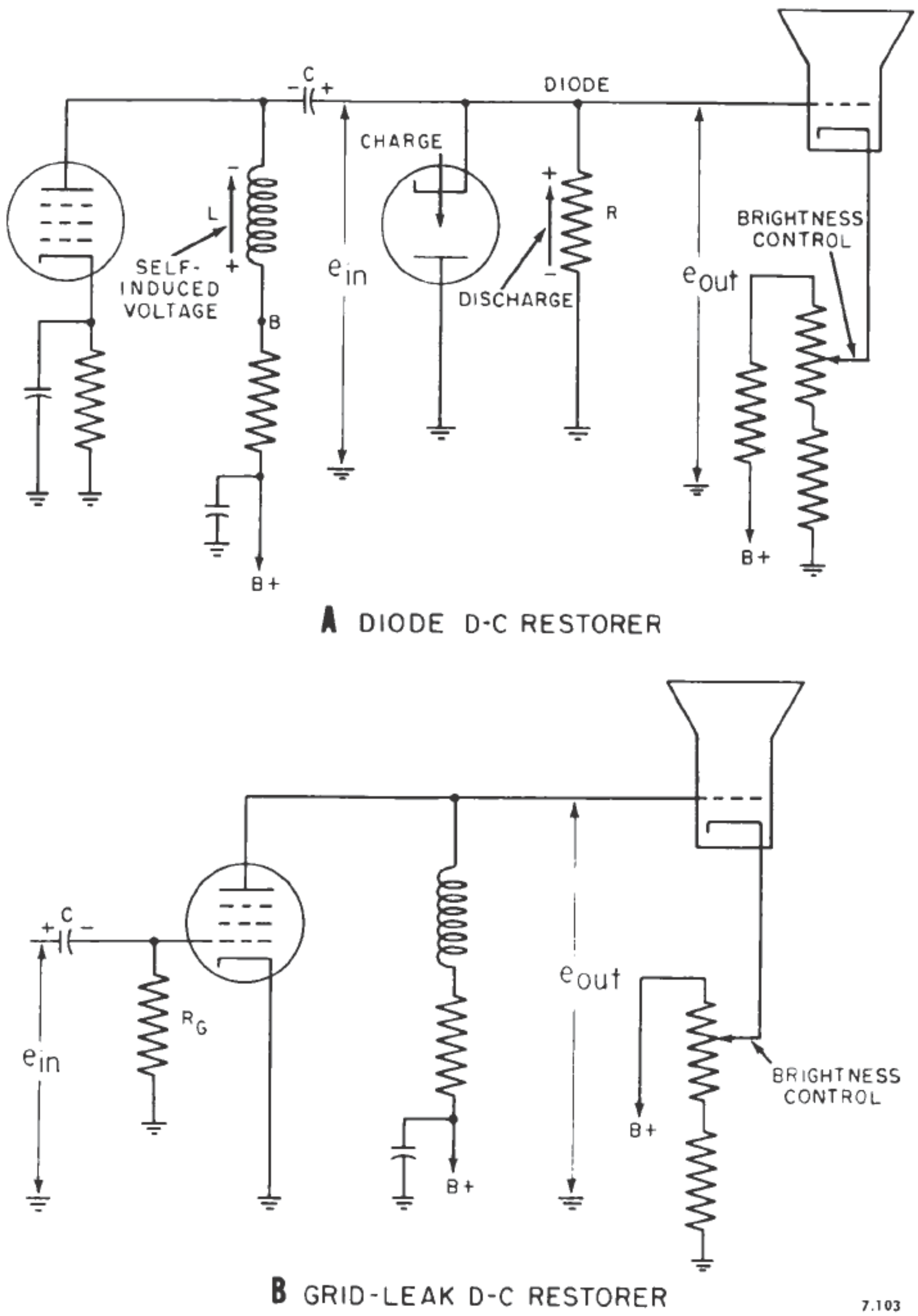

Figure 10-11.—Simplified circuits of d-c restorers.

After the vertical and horizontal sync signals have been removed (clipped) from the video signal, they must be amplified (if necessary) and separated from each other by means of filters. Following this, they are amplified and reshaped, according to the needs of the system, before they are applied to the oscillators. A block diagram of the synchronizing circuits is shown in figure 10-12.

The horizontal sync signal fires the horizontal oscillator at exactly the right instant to maintain the proper synchronization between

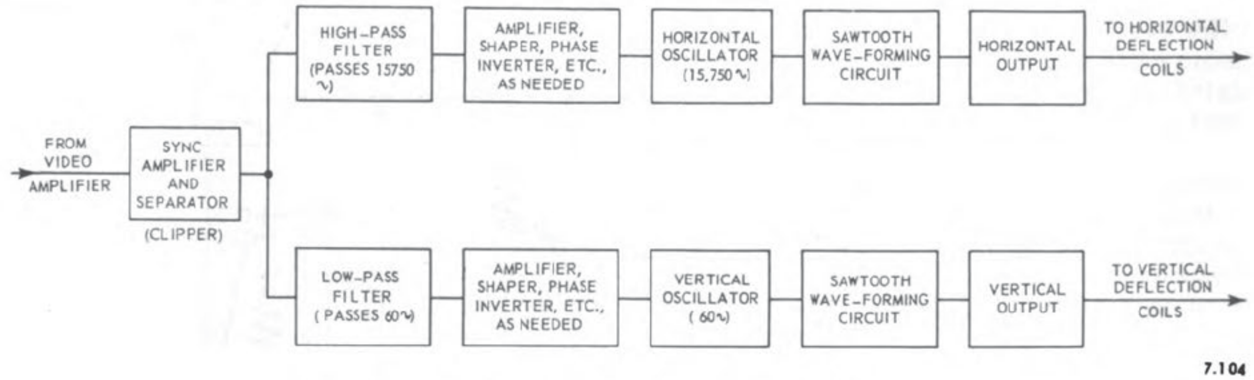

Figure 10-12.—Block diagram of synchronizing circuit.

the horizontal sweep in the receiver picture tube and the horizontal sweep in the transmitter camera tube. The output of the horizontal oscillator is formed into a sawtooth waveform; it is then amplified and applied to the horizontal deflection coils.

The vertical sync signal fires the vertical oscillator at the right instant to maintain the proper synchronization between the vertical sweep in the receiver picture tube and the vertical sweep in the transmitter camera tube. As in the case of the horizontal oscillator output, the vertical oscillator output is formed into a sawtooth wave (modified into a trapezoidal form); it is then amplified and applied to the vertical deflection coil.

SYNC SEPARATORS

Sync separation, or sync clipping, may be accomplished by the use of circuits employing diodes, triodes, or pentodes. A simplified circuit of a diode sync separator is shown in figure 10-13. During the time the sync tip voltage is applied to the input the diode plate is positive with respect to the cathode, and capacitor C is charged through the low resistance of the conducting diode. Between pulses,

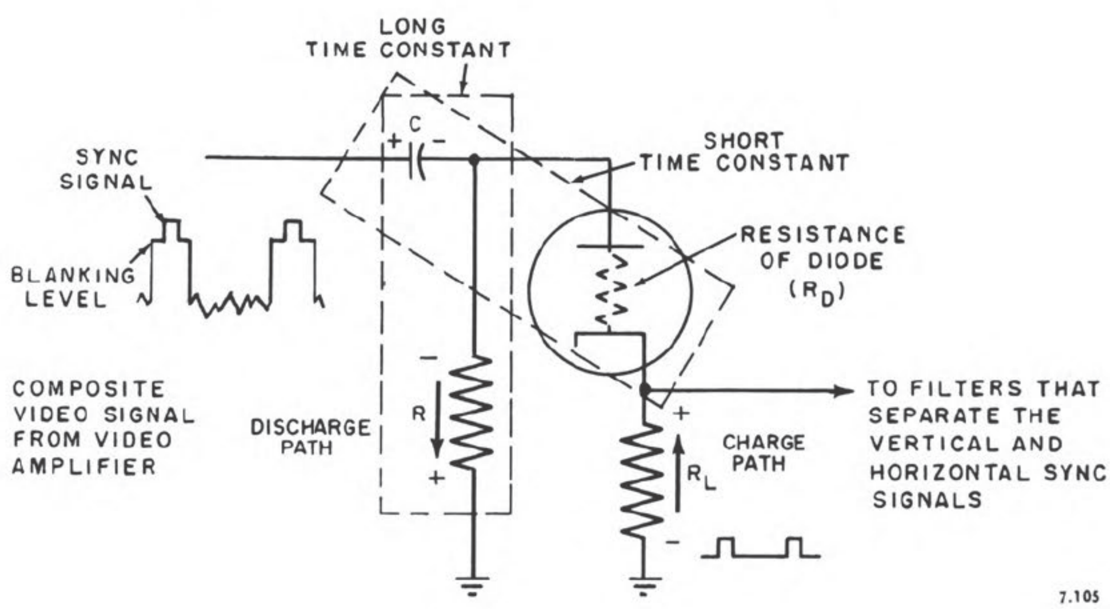

Figure 10-13.—Diode sync separator.

capacitor C discharges through R and thus maintains a negative bias between plate and ground; and this cuts off all signals up to the blanking level. The bias is maintained at approximately the blanking level, and only the sync signal causes pulses of current to flow through R_L, across which the output is taken.

The output pulses consist of the horizontal sync pulses, the equalizing pulses, and the serrated vertical sync pulses. These pulses are fed to filter circuits that separate the vertical sync pulses from the horizontal sync pulses.

The problems involved in removing (sync clipping) the sync signals from the composite signal, and in amplifying, separating, and utilizing those signals to control the horizontal and vertical oscillators are treated only in a general way in this section. There are many methods of solving these problems and therefore a detailed treatment of each method is not possible in this training course.

SEPARATION OF VERTICAL AND HORIZONTAL SYNC PULSES

Because the repetition rate of the vertical sync pulses is 60 pulses per second and that of the horizontal sync pulses is 15,750 pulses per second, they may be separated by filters.

One filter, the high-pass filter, is used to pass and shape the trigger voltages for the horizontal oscillator (a multivibrator or blocking oscillator) as shown in figure 10-14. The circuit in this figure has a short time constant

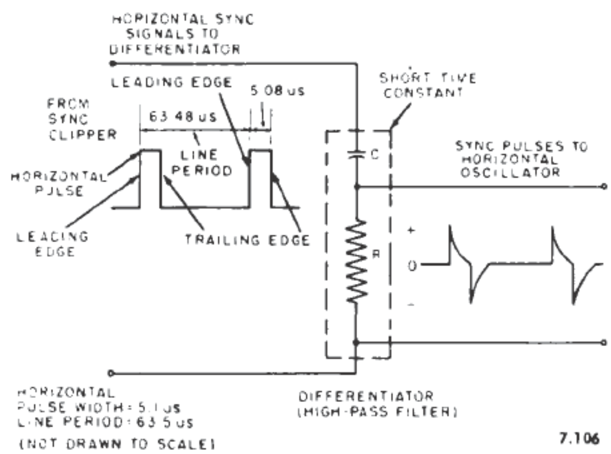

Figure 10-14.—High-pass filter for horizontal sync pulses.

with respect to the period (width) of the horizontal pulse. The output signal is developed across R.

The leading edge of the square-wave input pulses causes a rapid charge of C through R. The trailing edge causes an equally rapid discharge of C through R. The flow of charge and discharge current through R causes the sharp spikes of output voltage, as shown in figure 10-14. Only one spike in each pair (for example, the positive spike) is needed to trigger the horizontal oscillator. The other spike of the pair occurs at a time when the oscillator is insensitive to triggering pulses.

The low-pass filter used to pass and shape the trigger voltages for the vertical oscillator (a multivibrator or blocking oscillator) is shown in figure 10-15. The R-C time constant is long with respect to the width of each serration in the vertical pulse. Because of the long time constant in the integrator circuit, C does not have time to discharge during the interval between serrations. However, because the R-C time constant is short compared to the period of the 60 cycles vertical oscillator pulses, C charges up to the peak value during the time that the vertical pulse is applied (190 μs in the figure) and discharges to zero before the vertical pulse arrives.

The short time constant (with respect to the width of each horizontal pulse) of the differentiator circuit shown in figure 10-14, plus the fact that the output is taken across the resistor, renders this circuit relatively insensitive to the longer, lower-repetition-rate pulses that control the vertical oscillator.

Because of the long time constant (with respect to the width of each horizontal pulse) of the integrator circuit shown in figure 10-15, the horizontal pulses have very little effect, and the equalizing pulses have even less effect. The only pulse that produces a useful output is the serrated vertical pulse. Sixty of these pulses occur each second, 30 for each of the 2 fields. The vertical pulses are serrated to provide the triggering action for the horizontal oscillator during the vertical retrace period.

FORM OF THE SYNCHRONIZING PULSES

So far in our discussion we have said little about the special form of the synchronizing

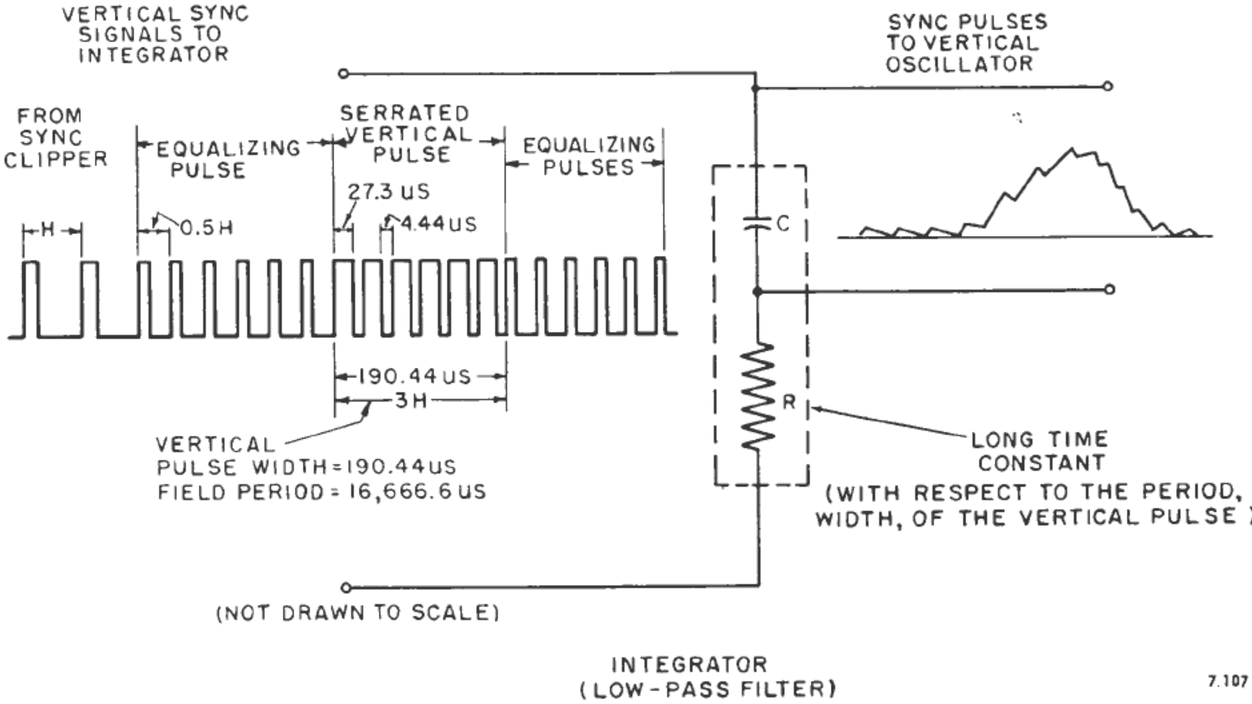

Figure 10-15.—Low-pass filter for vertical sync pulses.

pulses. The form and the timing of the synchronizing pulses are such that the horizontal and vertical oscillators are triggered at exactly the right instant to keep the sweep in the camera tube and the sweep in the picture tube locked in step. Because the horizontal oscillator must be triggered during the vertical pulse (to prevent the horizontal oscillator from drifting out of control), the vertical pulse is serrated, as shown in figure 10-16. That is, the vertical pulse is chopped into six pieces. The fluctuations resulting from serrations do not affect the operation of the vertical oscillator, but serve only to keep the horizontal oscillator properly triggered.

In addition to the serrations in the vertical pulse, equalizing pulses are necessary before and after each vertical pulse. The necessity for the equalizing pulses, labeled E in figure 10-16,B, may be explained as follows: first, it is assumed that no equalizing pulses are used, as in figure 10-16,A. If the vertical pulse is inserted at the end of the field, which occurs simultaneously with the end of a full horizontal line (part (1)); the firing potential of the vertical oscillator is reached at the correct time to produce the desired interlaced scan.

If the vertical pulse is inserted at the end of a field, which occurs simultaneously with the end of a half horizontal line (part (2)), the firing potential of the vertical oscillator is reached too early. This results from the fact that the slight charge in C, due to each horizontal pulse, does not have time to leak off before the vertical pulse arrives. The residual voltage across C, plus the voltage due to the vertical pulse, causes the vertical oscillator to fire too soon.

Secondly, the situation is corrected, as shown in figure 10-16,B, by the use of equalizing pulses. The buildup of the vertical pulse across C now begins at the same point (for example, point 1 on the X axis) regardless of whether the vertical pulse arrives at the end of a full line or at the end of a half line. In other words, the equalizing pulses cause the potential on C to be at the same level (at the same time the vertical pulse arrives) regardless of whether the vertical pulse occurs at the end of a half line or at the end of a full line. Although not shown in the figure, equalizing pulses are also used after the vertical pulses.

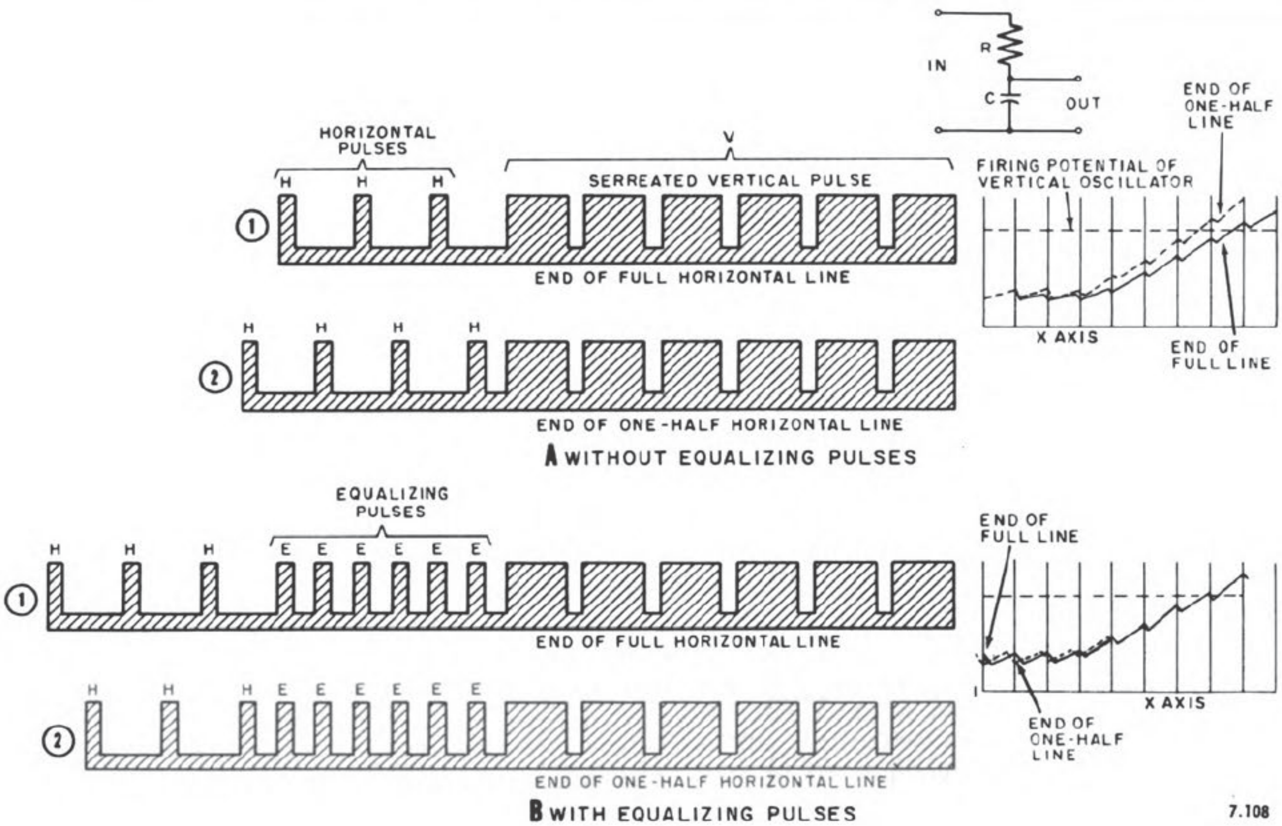

Figure 10-16.—The form of the synchronizing pulses.

A better idea of the form of sync pulses may be obtained from a study of figure 10-17. It may be seen that a number of horizontal scans are lost during the vertical flyback time.

SWEEP CIRCUITS

After being separated and shaped, the horizontal and vertical sync pulses are applied to the horizontal and vertical sweep oscillators, respectively, so that they may be triggered at the correct instant to synchronize the receiver with the transmitter. Both the vertical and horizontal sweep oscillators, when fed into the correct circuits, produce current sawtooth waveforms.

The sawtooth waveforms produced by the horizontal sweep oscillator are amplified and applied to the picture tube in a manner that will cause the electron beam to be deflected (swept) horizontally across the face of the tube. Likewise, the waveforms produced by the vertical sweep oscillator cause the electron beam to be deflected (relatively slowly) from the top to the bottom of the picture tube.

Multivibrators and blocking oscillators are two types of resistance-capacitance oscillators that are commonly used in the sweep circuits (vertical and horizontal) of television receivers. At this point it will be helpful to review these oscillators in *Basic Electronics*, NavPers 10087-A. In the last part of this chapter, neon sawtooth generators and multivibrators are explained in considerable detail.

BLOCKING OSCILLATOR

A simplified version of a blocking oscillator is shown in figure 10-18,A. When plate and filament voltages are applied to the tube, plate current begins to flow. A voltage is induced in the grid circuit (via transformer T) that makes the grid positive with respect to ground, and the plate current is thereby increased rapidly

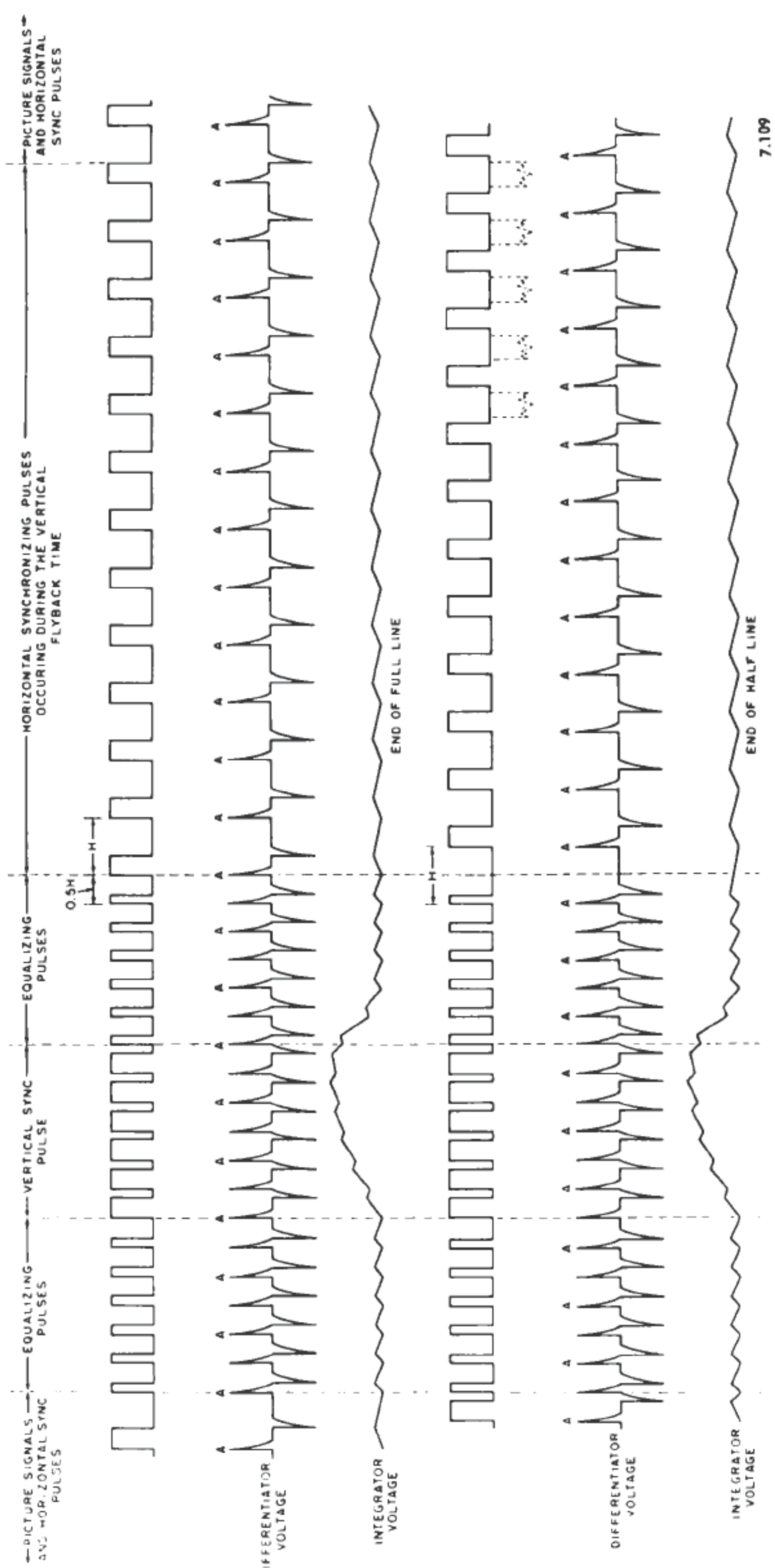

Figure 10-17.—Form of sync pulses showing the output integrator and differentiator voltages.

to saturation. Capacitor C2 charges rapidly during the time that grid current flows. At saturation the plate current and field about T stop increasing. The voltage induced in the secondary of T drops to zero, and therefore the induced positive grid voltage drops to zero. Capacitor C2 begins to discharge through R2 and the plate current falls; the field of T collapses. The voltage induced in the secondary of T is now of a polarity that aids the discharge of C2. The grid, therefore, becomes more negative with respect to ground, and plate current falls rapidly to zero. When the plate current is zero, the voltage induced in T is zero. Capacitor C2 continues to discharge relatively slowly through R2. This action maintains a negative charge on the grid for an appreciable length of time. The time (equal to the period between the pulses produced by the oscillator) necessary for the negative charge to be reduced sufficiently to cause the tube to conduct again depends on the value of adjustable resistor R2. When the tube begins to conduct again, the cycle is repeated.

A sawtooth output could be tapped off across R3, but the waveform would be lacking in linearity and stability because of the loading effect on the oscillator. The sawtooth wave is developed because C3 charges relatively slowly through R3 during the relatively long time that V_1 is cut off and discharges quickly through the tube during the relatively short time that the tube is conducting.

The sawtooth output is commonly obtained across the load resistor of a discharge tube. This arrangement is shown in figure 10-18,A. The sharp positive pulse developed across R2 is coupled to the grid of V2. During the period when the positive pulse is not applied to the grid of V2, C4 charges relatively slowly at a uniform rate through R4; when the positive pulse is applied, C4 discharges rapidly through V2. The sawtooth voltage is therefore developed across R4.

MULTIVIBRATOR

One type of multivibrator circuit, showing the sync input and sawtooth output, is shown in figure 10-18,B. The sync pulses can control the firing of the multivibrator if the frequency of the multivibrator is close to the repetition rate of the sync pulses. A detailed explanation of basic multivibrator operation is given in

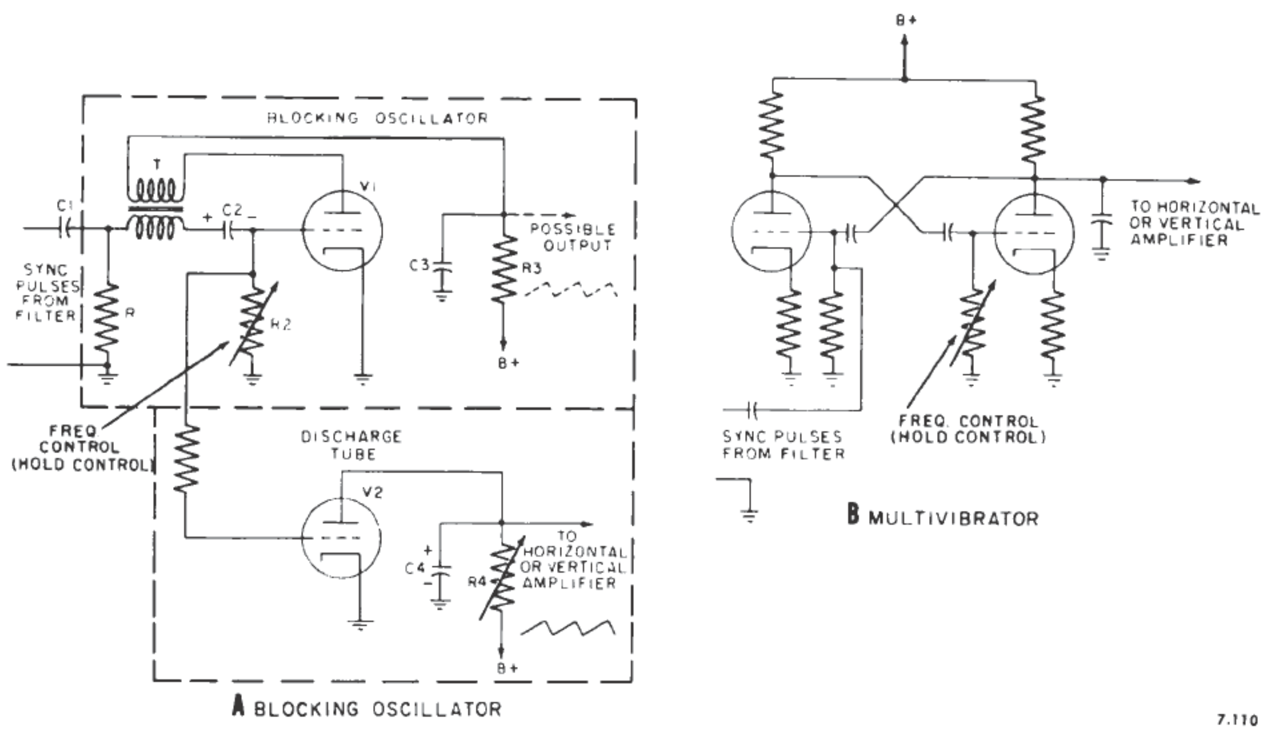

Figure 10-18.—Television sweep oscillators.

Basic Electronics, NavPers 10087-A, and a review of this material might prove helpful at this time.

HORIZONTAL OSCILLATOR AUTOMATIC FREQUENCY CONTROL

In the sweep circuits discussed thus far, the horizontal and vertical sync pulses are fed from the filter directly to the horizontal and vertical sweep oscillators. This simple, direct system would be satisfactory if it were not for the presence of noise pulses that may cause the oscillators to fire at the wrong time. When the vertical oscillator fires at the wrong time, the picture is not properly synchronized vertically. That is, the picture bounces, or moves in jumps upward or downward across the screen. When the horizontal oscillator fires at the wrong time, the picture is not properly synchronized horizontally. That is, the picture tears or becomes streaked, giving the appearance that the picture is jumbled.

Although noise pulses may effect the operation of both the vertical and the horizontal oscillators, by far the worse effect is felt by the horizontal oscillator. The long time constant of the vertical filter makes it insensitive to the short bursts of noise energy, and the effect on the vertical oscillator is not generally objectionable. In closed circuit TV, noise from electrical machinery can be just as destructive as atmospheric noise in a conventional home TV system.

The short time constant of the filter that feeds the sync pulses to the horizontal oscillator will permit the passage of short bursts of noise energy. Consequently, it is necessary to employ a control circuit that will effectively isolate the horizontal oscillator from the effects of noise pulses, and at the same time will permit the sync pulses to assume control.

Two systems that will isolate the horizontal sweep oscillator from the effects of noise bursts are shown in the block diagrams of figure 10-19. In the system shown in part A, two signals are applied to the frequency discriminator. They are horizontal sync signals and horizontal sweep oscillator signals. The frequency discriminator compares the frequency (or phase) of these signals and produces an output d-c voltage that depends on the difference between frequency (or phase) of the two signals. The output voltage, normally varying at a relatively slow rate, is fed via a low-pass filter to the grid of the reactance tube. This tube functions in such a manner that its output will change the frequency of the horizontal sweep oscillator to maintain its frequency exactly the same as that of the incoming horizontal sync pulses. Reactance tubes and frequency discriminators are treated in *Basic Electronics*.

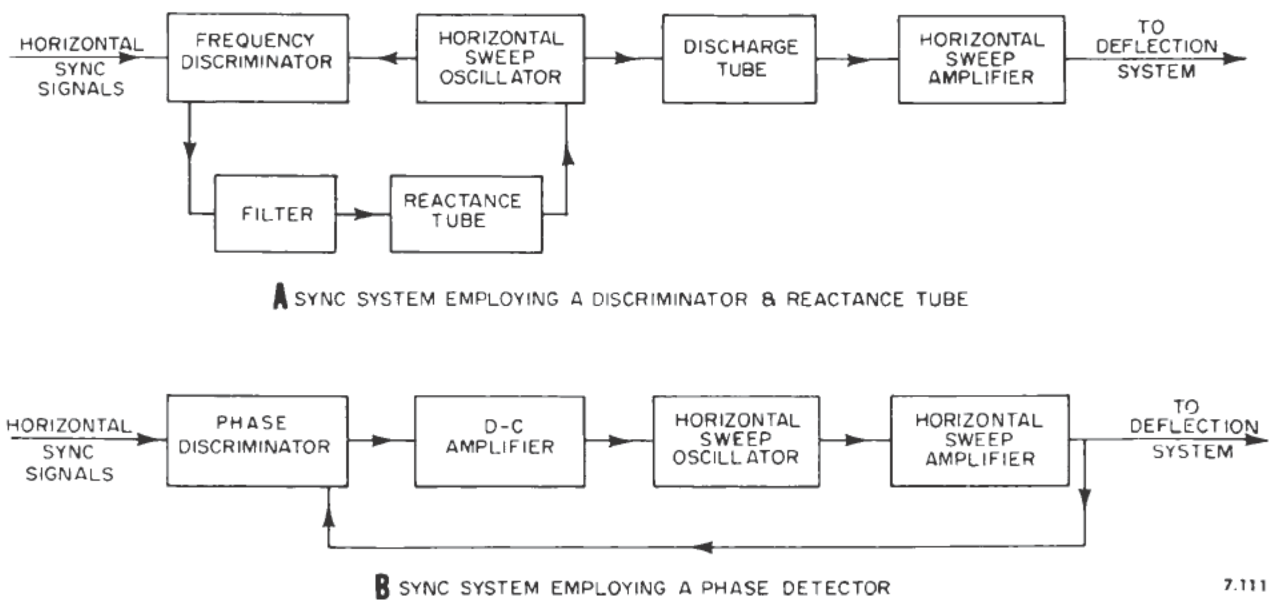

Figure 10-19.—Systems of horizontal sync control.

The second method of isolating the horizontal sweep oscillator from the noise bursts is shown in figure 10-19, B. As in the previous system, a frequency (or phase) discriminator is used. It compares the sync-signal input from the filter or sync amplifier with the input feedback from the horizontal sweep amplifier and produces a d-c output that is proportional to that difference. This d-c output is amplified and used in such a way as to cause the frequency of the horizontal sweep oscillator to lock in step with the incoming sync signals.

ELECTROMAGNETIC DEFLECTION SYSTEM

Electromagnetic rather that electrostatic deflection is commonly employed in television receivers. Whereas sawtooth VOLTAGE waves are used in electrostatic deflection, sawtooth CURRENT waves are used in electromagnetic deflection.

More power is needed in the horizontal deflection system of a television receiver because of the greater number of deflections per unit time that must be accomplished by the horizontal deflection circuit. Because of the higher frequency involved, there are additional transformer and circuit losses. The horizontal deflection circuits must therefore be designed to handle much more power than the vertical deflection circuits.

If the deflection coils of a television receiver possessed inductance only, a properly applied sawtooth wave of voltage would cause a sawtooth current wave to flow through the coils. However, the deflection coils have the property of resistance as well as inductance, and therefore a modified sawtooth voltage wave must be applied to the coils. The desired modified voltage wave has a trapesoidal form as shown in figure 10-20. In this instance, the desired voltage waveform is developed across the output plate-to-ground circuit of the discharge tube—that is, across C and R3. Resistor R3 has a low value, and has negligible effect during charge time.

The sweep amplifier for magnetic deflection is similar to the output stage of a radio receiver, except for the nature of the load. The simplified circuit of a vertical amplifier (the output stage) is shown in figure 10-21.

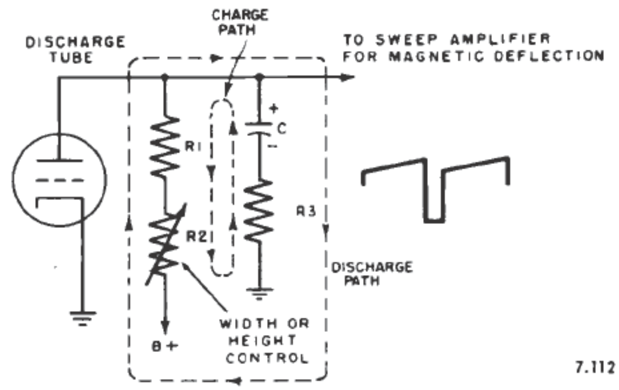

Figure 10-20.—Method of generating trapezoidal voltage waves.

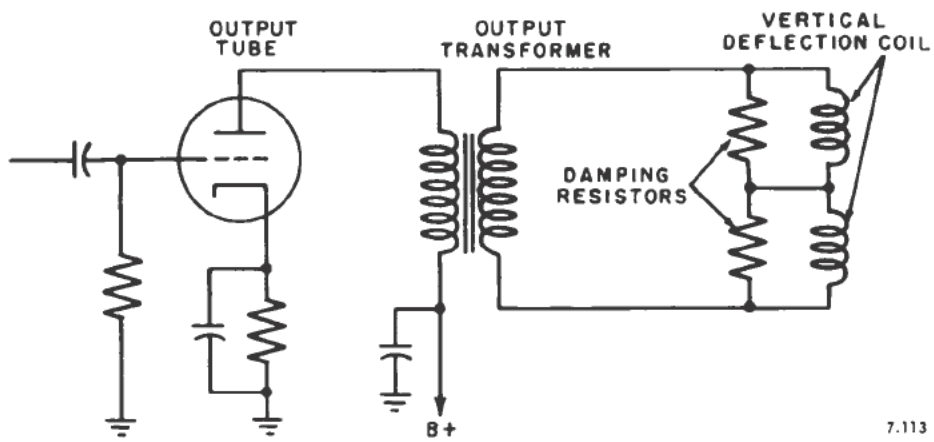

Figure 10-21.—Vertical amplifier.

There is a tendency for the inductance of the vertical coils, acting with the distributed capacitance, to set up spurious oscillations. These oscillations may be damped out, in the case of the vertical deflection system, by resistors connected across the vertical deflection coils as indicated in the figure. A more complex system of damping is generally employed with horizontal deflection systems.

HIGH-VOLTAGE SUPPLY

A simplified circuit of a flyback (or kickback) high-voltage power supply commonly used in television receivers is shown in figure 10-22. In this high-voltage power supply the horizontal output transformer serves two purposes. It

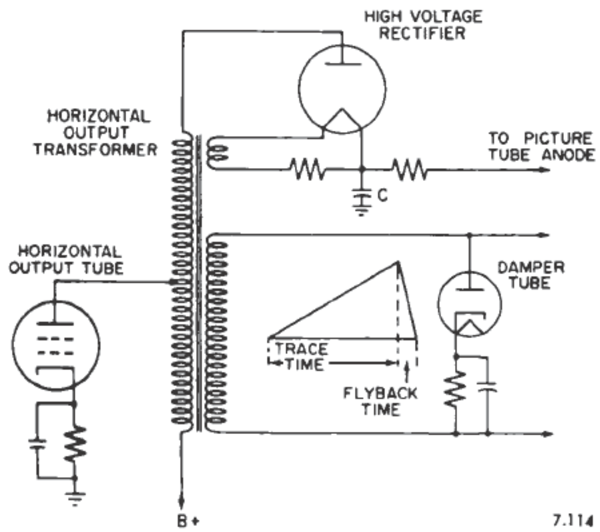

Figure 10-22.—Simplified circuit of flyback high-voltage power supply.

couples the amplified horizontal sweep pulse of current to the horizontal deflection coils, and it serves as a high-voltage auto transformer.

Because the flyback time is less than $10 \mu s$ and both the inductance and the current change are relatively large, the induced voltage is very high. In some large screen picture tubes the voltage may be as high as 30 kv. Obviously, this voltage is dangerous, and care must be taken to see that the set is deenergized and that capacitor C is discharged before servicing the receiver.

During the time of the horizontal sweep the current through the output transformer builds up steadily, and simultaneously, the magnetic field builds up. During the flyback time the current is reduced sharply, and the magnetic field collapses. A large voltage is thereby induced in the primary winding. This voltage is applied between the plate of the high-voltage rectifier and ground, and pulses of current flow through the rectifier during the flyback time. Because of the large number (15,750) of pulses occurring each second, a small capacitance may be used in the filtering arrangement.

The horizontal output transformer commonly has a powdered-iron core to avoid the annoying vibrations that might be set up at the horizontal sweep frequency if a laminated core were used. The filament power supply is obtained from a secondary winding composed of one or two turns of wire.

In this type of circuit, failure of the low-voltage supply automatically removes the high voltage. This is an advantageous arrangement because if the horizontal sweep were removed, without removing the high voltage at the same time, the screen might be damaged at the point where the electron beam strikes it.

The damper tube is used to dissipate the energy contained in the oscillations set up in the output stage during the horizontal flyback time.

Some closed circuit TV viewers use an r-f type power supply to generate the high voltages necessary to operate the picture tube. This method is satisfactory because of the low current requirements. In this type of power supply, part of a winding containing many turns of wire is used as the inductance of an oscillator tuned circuit. The resonant stepup voltage characteristic of a tuned circuit is used to induce a high voltage in the entire winding. This voltage is rectified and filtered in the normal manner. However, because of the high frequencies used, simple R-C filters are sufficient.

SUMMARY

The future importance of closed circuit television in naval operations can be visualized by listing some current applications.

(1) Submarines operating under ice in polar regions used closed circuit TV to examine the undersurface of the ice. In this application, TV supplements other equipments to inform the submarine commander in regard to obstacles in his path.

(2) A waterproof camera can be lowered over the side of a ship so that inspections for hull or

propeller damage can be made without the services of a diver, and interested parties may view actual conditions.

(3) A camera can be permanently mounted on the overhead in CIC to permit simultaneous viewing of the CIC plotting board in several locations.

(4) Demonstrations can be made in a small area and viewed at several points by many people who could not get into the demonstration area.

Personnel maintaining closed circuit TV equipment will find that a good working knowledge of the fundamentals of electricity and electronics circuits is absolutely essential. As in all electrical or electronic work, there is no substitute for the ability to "think through" a circuit, and to apply "effect-to-cause" reasoning.

A working knowledge of an oscilloscope is required because it is often necessary to observe wave shapes in order to isolate trouble. The instruction book for the specific equipment will show points to which the scope should be connected and the wave shapes that should be visible at those points.

It is well to remember that one of the first steps in servicing closed circuit TV equipment is to isolate the trouble to either the camera or the viewer. In the system using a master oscillator to generate all wave shapes and pulses, a failure in both camera and viewer at the same time would indicate trouble in the master oscillator section. In the system using a conventional TV set as the viewing unit, failure to get a picture might only mean that the tuner was set to the wrong channel. Therefore, before tearing into gear, eliminate the more or less obvious possibilities.

QUIZ

1. What are the three main divisions in a home TV system?
2. What is the name of the light sensitive surface in the camera tube?
3. What amplitude modulates the video carrier?
4. What type of modulation is used for the audio carrier?
5. What signals are in the frequencies picked up by the receiving antenna?
6. What keeps the entire video system in step?
7. What is the name of the camera pickup tube used in modern closed circuit TV systems?
8. What is the low-light level for using the image orthicon?
9. How many scan lines are there in a commercial TV picture?
10. How is the scanning beam deflected in the image orthicon?
11. What frequency characteristic must the picture amplifier have?
12. What is the horizontal sweep frequency in a standard home TV receiver?
13. How many picture elements in an image each second if there are assumed to be 1000 picture elements per line?
14. What band pass is necessary to pass signals without distortion if there are assumed to be 1000 picture elements per line and each has a different charge?
15. Since two fields are necessary to complete one frame in interlace scanning, how many lines are scanned during the first field?
16. How often is the vertical sweep triggered?
17. What precedes and follows the vertical sync pulses?
18. How many lines are there in one picture frame of a modern closed circuit TV system?
19. What must the picture phase polarity be at the grid of the picture tube?
20. What is the result of poor frequency response in the video amplifier?
21. How many the shunting effect of distributed capacitance in a resistance coupled amplifier be compensated?
22. What happens to the d-c component of the video signal by its passage through the coupling capacitor of the video amplifier?
23. How may the vertical sync (60 cps) pulses be separated from the horizontal sync (15,750 cps) pulses?

24. What type of current waveforms produced by the vertical and horizontal sweep oscillators are applied to the picture tube?
25. What are the two types of R-C oscillators used in TV?
26. What type of CRT deflection is used in TV receivers?
27. What is the purpose of the resistors connected across the deflection coils?
28. What name is applied to the high-voltage power supply in a TV set?
29. What principle is used in r-f high-voltage power supplies?

CHAPTER 11

SHIP CONTROL ORDER AND INDICATING SYSTEMS

Ship control order and indicating systems include among others the engine order system, propeller order system, rudder order system, and rudder angle indicator system. These systems comprise units that pertain to ship control orders and indications. The units are either synchro transmitters, synchro receivers, or a combination of both, and operate on a standard synchro transmission system.

The units comprising the ship control order and indicating systems are enclosed in splash-proof metal cases designed for pedestal, or universal panel bulkhead) mounting depending on the stations in which they are located. Where required, windows for viewing dials are provided in the unit covers. The internal sub-assemblies can be withdrawn individually from the case for troubleshooting and repairs.

Cables are brought into the unit cases through watertight terminal tubes and the leads are connected to terminal strips or female connectors. The leads for the synchros, bell circuits, and other components are connected to corresponding terminal strips or male connectors within the cases.

ENGINE ORDER SYSTEM

The engine order system, circuit MB, is used to transmit the desired engine orders from the pilot house, open bridge, or secondary conning station to the enginerooms, firerooms (boiler operating stations), and superheat operator stations. Separate circuits are installed for the starboard engines (circuit 1MB) and the port engines (circuit 2MB).

A representative engine order system installed in a large ship is illustrated by the block diagram in figure 11-1. The system consists of various transmitters and indicators installed in the conning stations, enginerooms, and firerooms. A combined port and starboard engine order indicator-transmitter is installed in the pilot house, and sometimes in the secondary conning station and on the open bridge. This unit is electrically connected to a single indicator-transmitter with wrong-direction signal contacts in each throttle station. The wrong-direction signal contacts sound an alarm at the throttle station if the throttle operation is opposite to an acknowledged order.

A double engine order indicator is installed in throttle station 1 and in each fireroom operating station. The indicator in throttle station 1 receives and answers orders for the port engines only. The indicators in the fireroom operating stations receive the repeat-back orders for both the port and starboard engines. A single engine order indicator is also installed in throttle stations 1 and 4.

The entire main engine control is invested in throttle station 1. However, throttle stations 1 and 4, located on the starboard and port sides respectively, in the forward engineroom are called LEADING throttle stations, and throttle stations 2 and 3, located on the starboard and port sides respectively, in the after engineroom are called FOLLOWING throttle stations.

An engine order is originated at one of the conning stations by moving the operating handle of the double indicator-transmitter until the transmitter is over the selected order on the dial. The transmitted order is received on all indicators in the circuit. The order is answered by turning the operating knob on the indicator-transmitter at the FOLLOWING throttle station until the reply pointer of the transmitter is over the received order on the dial. The reply is received on the single engine order indicator at the LEADING throttle stations. The LEADING throttle station then replies in a similar manner and this reply is received on the double indicator-transmitter in the conning station that originated the order. Thus, the conning station is assured that the transmitted order has been correctly received and interpreted at both LEADING and FOLLOWING throttle stations.

The units in the enginerooms and boiler operating stations are provided with bells that ring each time a transmitted order is originated

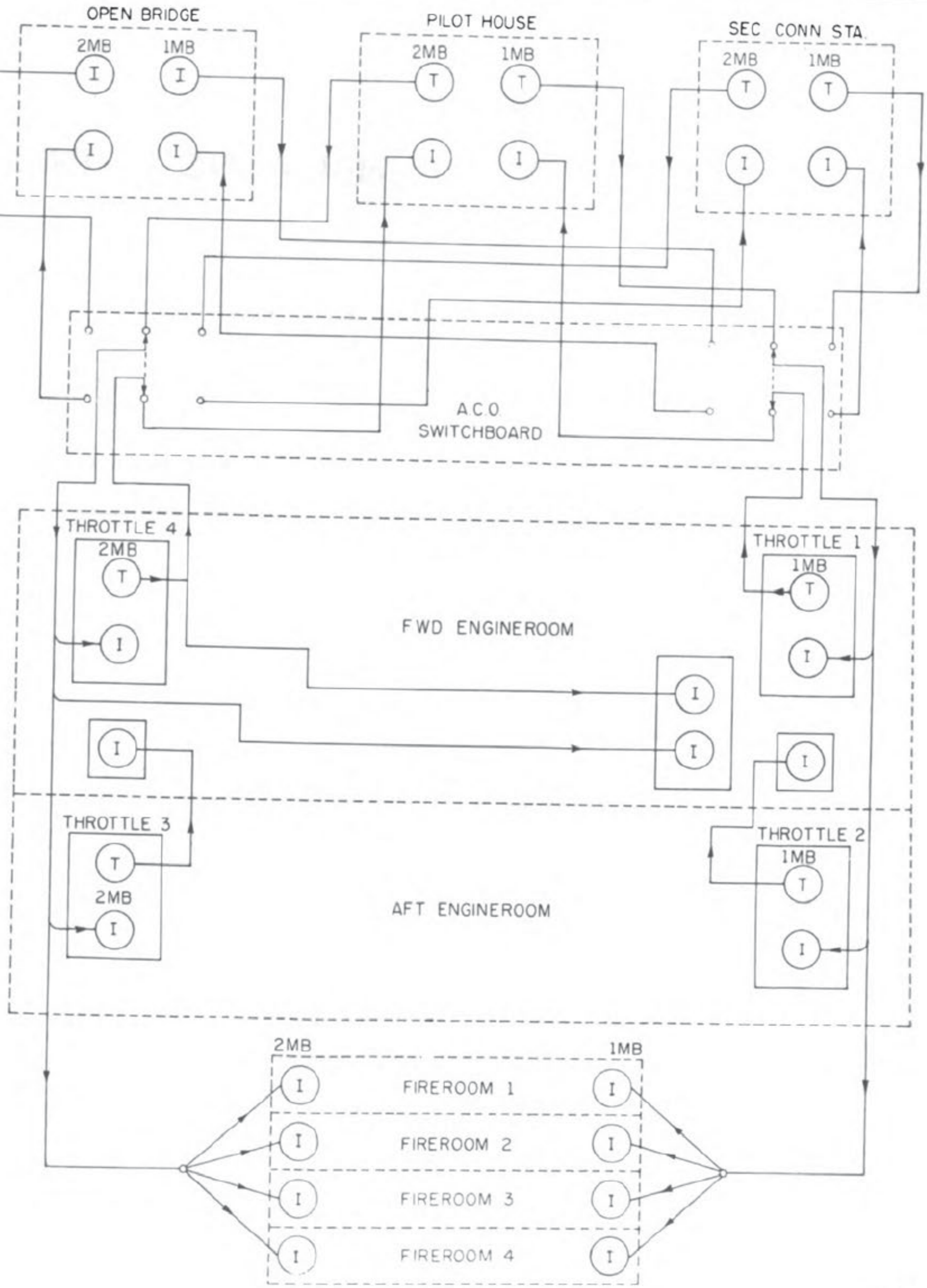

Figure 11-1.—Block diagram of engine order system.

at the conning station. An audible signal is not provided on the circuits between the forward and after enginerooms.

A selector switch is installed on the ACO switchboard for selecting the double engine order indicator-transmitter to control the circuit. The after engineroom can answer directly to the conning station in an emergency. Cutout switches are installed on the ACO switchboard for the indicators in all units except those between the after engineroom and the forward engineroom. Cutout switches and transfer switches are combined for circuits 1MB and 2MB.

DOUBLE ENGINE ORDER INDICATOR-TRANSMITTER

The double engine order indicator-transmitter installed in each conning station (fig. 11-2) is used to transmit engine orders and to receive acknowledgement of these orders. It is a dual unit with a port and a starboard indicator-transmitting subassembly, each operating independently of the other.

The double engine order indicator-transmitter installed in each conning station is frequently combined in one console or stand with the propeller order indicator-transmitter. These units are used to indicate and to transmit engine orders and propeller orders respectively. The double engine order indicator-transmitter is of the drum type and forms the top section of the complete combined assembly. The unit consists of two synchro receivers and two synchro transmitters indicating on two fixed dials (port and starboard) by concentric revolving pointers.

Synchro types are indicated in figure 11-3. The receivers and transmitters are mounted on individual baseplates to form two complete and identical indicator-transmitter subassemblies that are mounted in each side of the drum-type housing for port and starboard circuits.

The transmitter of each subassembly is positioned by a side operating handle which is an extension of the transmitter pointer. The operating handle with its pointer is connected through a dovetail coupling and gears to the shaft of a synchro transmitter. A detent wheel secured concentrically to one of these gears actuates a microswitch through a roller and lever arm to close the alarm bell circuit when

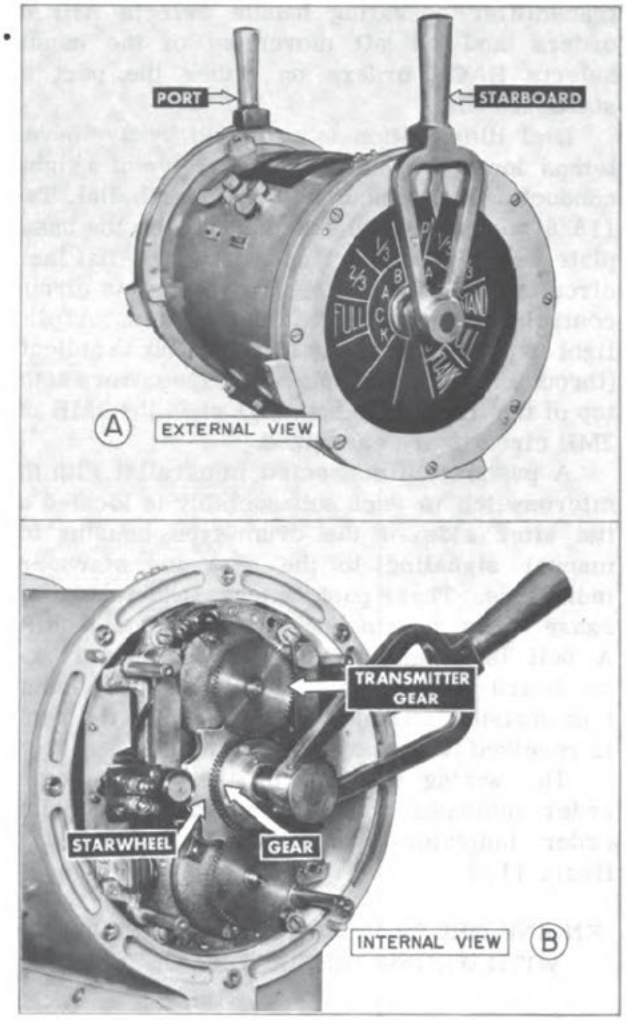

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Figure 11-2.—Double engine order indicator-transmitter.

the operating handle is moved. This action causes a bell to ring on the engineroom unit. A spring-operated lever stop is provided in the operating handle to lock the transmitter pointer in the selected position.

The indicator pointer of each subassembly is secured directly to the shaft of a synchro receiver. This pointer indicates the reply from the engineroom unit by matching the transmitted order on the dial.

The dials are attached to the sides of the drum-type housing. They are made of a translucent material having a dull white background with black markings. The dial markings are so arranged that a forward movement of either

transmitter operating handle selects AHEAD orders and an aft movement of the handle selects BACK orders on either the port or starboard dial.

Dial illumination is provided by five 6-volt lamps located around the perimeter of a light-conducting panel mounted behind each dial. Two 115/6-volt transformers mounted on the baseplates supply the port and starboard dial lamp circuits. A rheostat in series with this circuit controls the intensity of illumination. A pilot light is provided in each subassembly to indicate (through two windows placed in the covers at the top of the drum-type housing) when the 1MB and 2MB circuits are energized.

A pushswitch connected in parallel with the microswitch in each subassembly is located on the after side of the drum-type housing for manual signaling to the port and starboard indicators. These pushswitches, when operated, cause bells to ring on the engineroom units. A bell is mounted externally on the port and starboard side of the pedestal below the drum-type housing. These bells ring when the reply is received from the engineroom units.

The wiring diagram of the double engine order indicator-transmitter and the propeller order indicator-transmitter is illustrated in figure 11-3.

ENGINE ORDER INDICATOR-TRANSMITTER WITH WRONG-DIRECTION CONTACTS

The engine order indicator-transmitter with wrong-direction signal contacts installed in each throttle station is used to indicate orders pertaining to engine speed and direction from the conning station and to acknowledge these orders. The wrong-direction signal contacts close an alarm bell circuit when the movement of the throttle will cause the ship to move in a direction opposite to the order acknowledged to the conning station in control.

The unit consists of a 23TR6 synchro receiver and a 37TX6 synchro transmitter indicating on a fixed dial by two revolving concentric pointers. The receiver and transmitter are mounted on a common baseplate to form a complete indicator-transmitter subassembly.

The indicator pointer marked ORDER is attached directly to the shaft of the synchro receiver and indicates the order from the conning station.

The transmitter pointer marked ANSWER is geared to the shaft of the synchro transmitter and is positioned by an operating knob to indicate the transmitted order. A detent wheel secured concentrically to one of the transmitter gears actuates a microswitch through a roller and lever arm to close the alarm bell circuit when the transmitter-operating knob is moved. This action causes a bell to ring on the conning station unit.

The wrong-direction contacts consist of two microswitches provided in the AHEAD and BACK positions of the transmitter operating handle. Each microswitch is connected in series with a microswitch at the main throttle valves. A cam attached to the detent wheel on the transmitter shaft operates a lever arm that controls the wrong-direction microswitches. If the engine direction acknowledgement is misinterpreted at the throttle, both of the series-connected microswitches are closed to provide a warning. This warning consists of a bell and a single dial (2-lamp) indicator containing a red glass lens located at each throttle station (not shown).

A pushswitch connected in parallel with the microswitch in the subassembly is provided for manual signaling to the conning station (fig. 11-4). This pushswitch, when operated, causes a bell to ring on the conning station unit. A bell on this unit rings each time an engine order is originated at the conning station. A pilot light indicates when the unit is energized.

DOUBLE ENGINE ORDER INDICATOR

The double engine order indicator installed in throttle station 1 (fig. 11-1) is used to indicate the transmitted 2MB engine order from the conning station to the port throttles and the answer from throttle station 4, after throttle station 3 has acknowledged the transmitted order.

The unit consists of a 23TR6 and a 31TR6 synchro receiver, indicating on a single fixed dial by two concentric revolving pointers. The receivers are mounted on a common baseplate to form a complete double indicator subassembly (fig. 11-5).

The indicator pointer marked ANSWER is secured directly to the shaft of the 23TR6

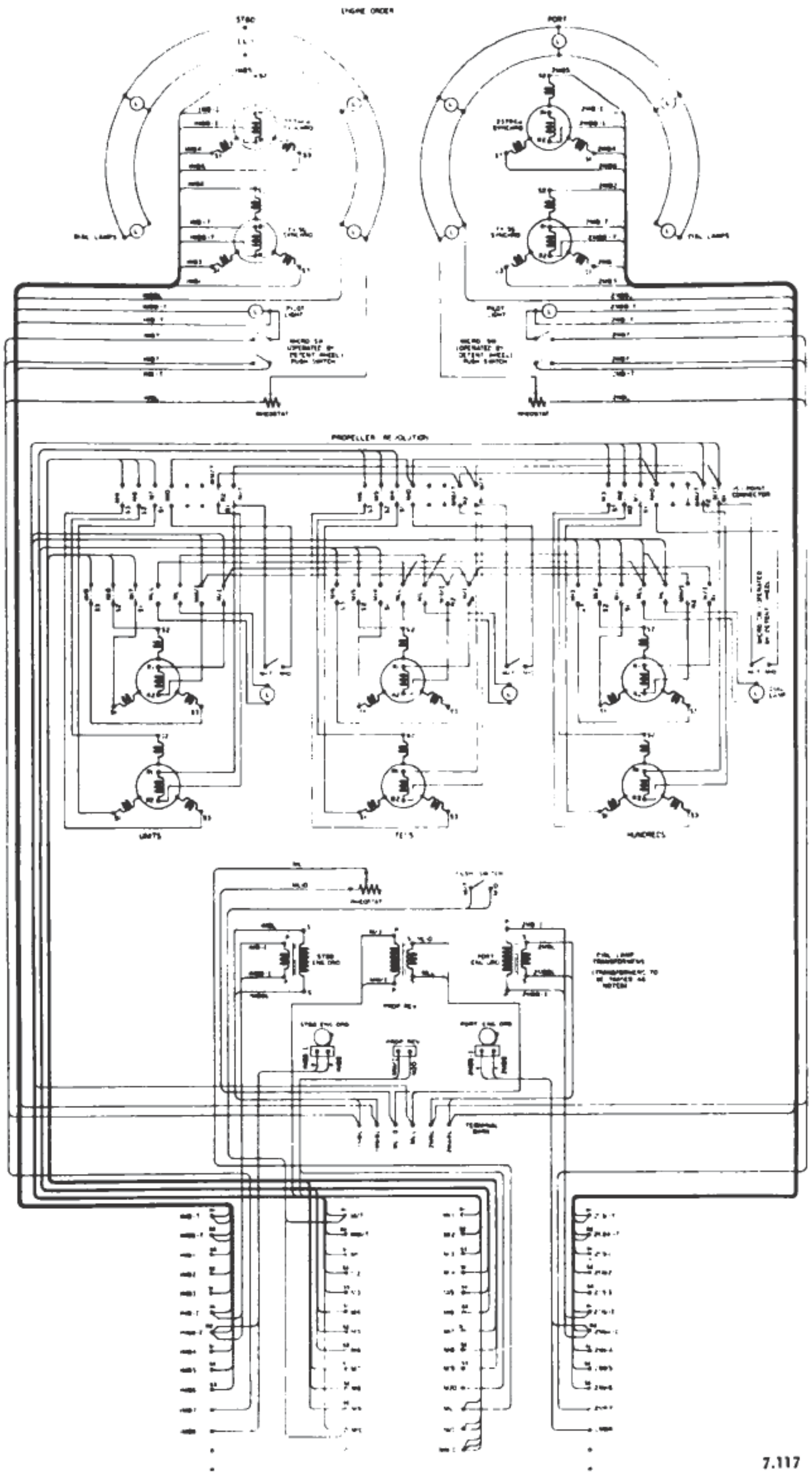

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Figure 11-3.—Wiring diagram of double engine order indicator-transmitter and propeller order indicator-transmitter.

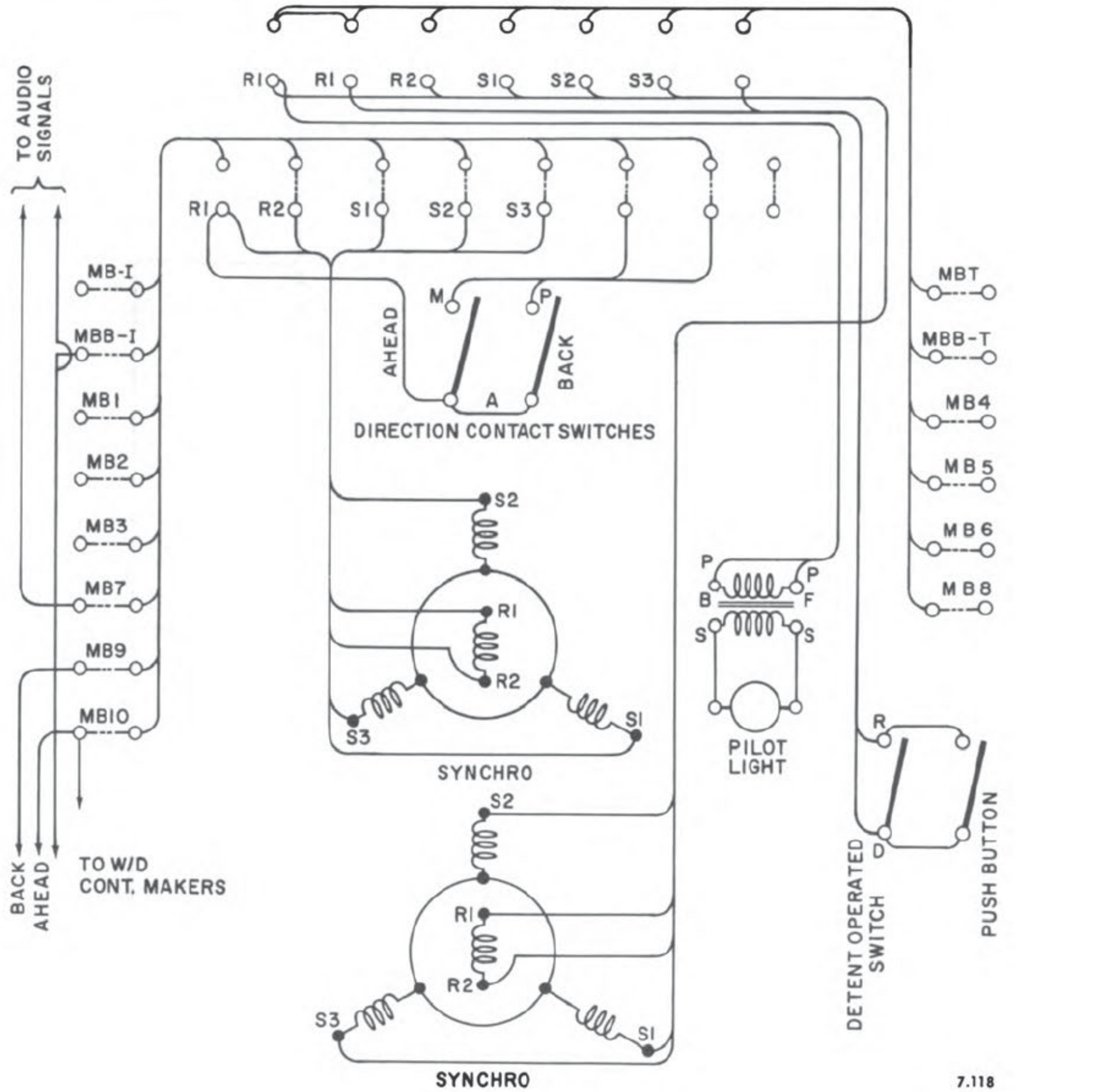


Figure 11-4.—Wiring diagram of engine order indicator-transmitter with wrong-direction contacts.

synchro receiver and indicates the acknowledgement of the engine orders from throttle station 4. The indicator pointer marked ORDER is geared to the shaft of the 31TR6 synchro receiver and indicates the transmitted engine order from the conning station.

The double engine order indicators installed in the boiler operating stations (fig. 11-1) are used to indicate engine orders transmitted from the port and starboard engine order transmitters. The units are electrically and mechanically identical to the double engine order indicator installed in throttle station 1 except for the pointer markings. The pointer marked P indicates orders relative to the port engine, and the pointer marked S indicates orders relative to the starboard engine.

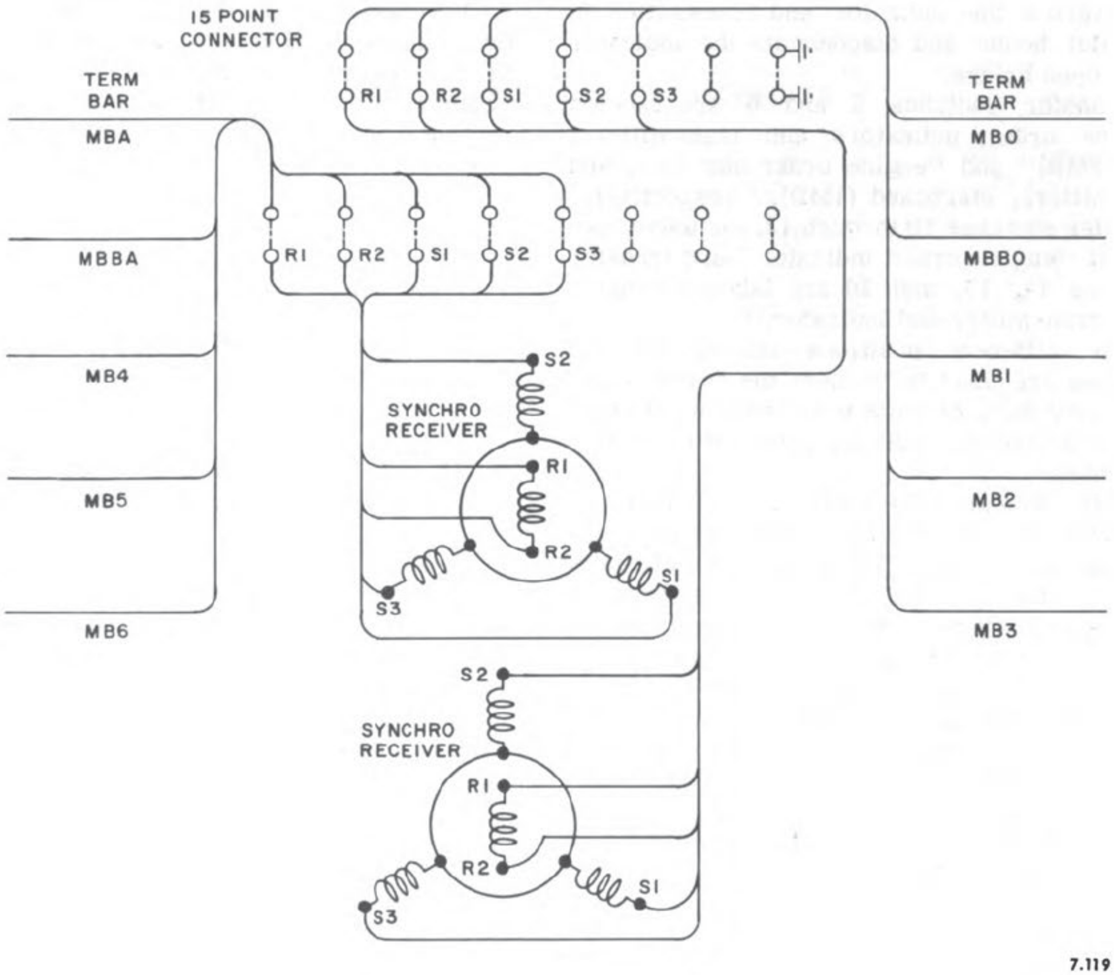


Figure 11-5.—Wiring diagram of double engine order indicator.

SINGLE ENGINE ORDER INDICATOR

The single engine order indicator installed in the throttle stations 1 and 4 (fig. 11-1) is used to indicate the reply from throttle stations 2 and 3 respectively after the transmitter order has been acknowledged by these stations.

The unit consists of a 23TR6 synchro receiver indicating on a fixed dial by a revolving pointer. The receiver is mounted on a baseplate to form a complete indicator subassembly. The indicator pointer is secured directly to the shaft of the 23TR6 synchro receiver. A bell rings on this unit each time the transmitted order is acknowledged.

ACTION CUTOUT AND TRANSFER SWITCHES

The operation of the engine order system (fig. 11-6) depends on the setting of the action cutout and transfer switches. For simplicity, switches 2, 3, and 4, which are for cable selection, are not shown.

TRANSFER SWITCH 1 is labeled "engine order indicators and transmitters." It has three positions marked (1) open bridge, (2) pilot house, and (3) central control station emergency. Position 1 energizes the indicator and transmitter in the open bridge and the indicator in the pilot house. Position 2 energizes the indicator and transmitter in the pilot house and the indicator in the open bridge. Position

3 energizes the indicator and transmitter in the pilot house and disconnects the indicator in the open bridge.

Transfer switches 5 and 6 are labeled "engine order indicators and transmitters, port (2MB)" and "engine order indicators and transmitters, starboard (1MB)," respectively. Transfer switches 10 through 13, inclusive, are labeled "engine order indicator" and transfer switches 14, 16, and 20 are labeled "engine order transmitter and indicator."

The different positions on the various switches are used to connect the engine order and repeat-back circuits to the various stations throughout the ship that are concerned with this information.

Action cutout (ACO) switches, like the transfer switches, are installed at various locations throughout the ship. The different positions of the individual switches are to add flexibility to the system. With this flexibility, many different combinations of normal operation are permitted, troubleshooting is facilitated, and the isolation of defective circuits is possible.

Normal operating conditions are obtained by setting the action cutout and transfer switches to the required positions. For example, if the pilot house is in control, the following switches are set at the positions indicated (fig. 11-6).

Switch	Position
1.	(2) pilot house
5, 6, 14, and 16	(2) normal
7, 8, and 9	(4) both
10, 11, 12, and 13.	(3) forward conning station
20.	(2) normal

A 1MB order from the pilot house is transmitted to the engine order indicator-transmitter in throttle stations 1 and 2. Throttle station 2 replies to the single engine order indicator in throttle station 1, and also to the double engine order indicators in firerooms 3 and 4. Throttle station 1 then replies to the pilot house and firerooms 1 and 2.

A 2MB order from the pilot house is transmitted to the engine order indicator-transmitters in throttle stations 3 and 4. Throttle station 3 replies to the single indicator in throttle station 4, and also to the double indicators in firerooms 3 and 4. Throttle station 4 then replies to the pilot house and firerooms 1 and 2.

Emergency operating conditions are obtained by setting the action cutout and transfer switches to the required positions. For example, if engineroom 1 is inoperative the following switches are set at the positions indicated.

Switch	Position
5 and 6.	(3) engineroom 2
7 and 8.	(4) both
9.	(2) off
10, 11, 12, and 13.	(3) pilot house
15 and 17	(2) off
16.	(3) forward conning station
18 and 19	(4) both
20.	(1) engineroom 2

A 1MB order from the pilot house is transmitted to the indicators in throttle station 2 with repeat-back to the pilot house, secondary conning station, and firerooms 1, 2, 3, and 4.

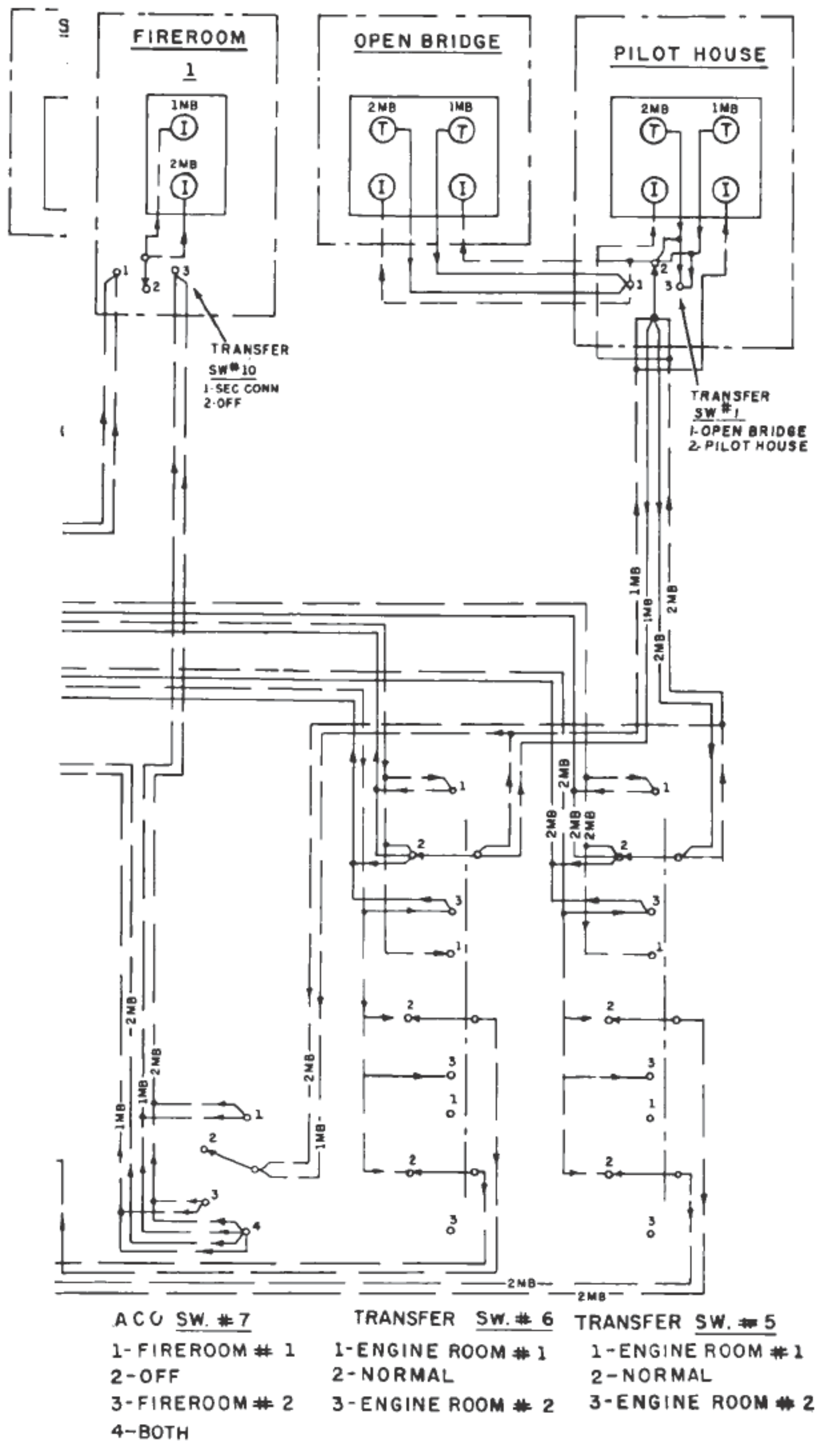
A 2MB order from the pilot house is transmitted to the indicators in throttle station 3 with repeat-back to the pilot house, secondary conning station, and firerooms 1, 2, 3, and 4.

PROPELLER ORDER SYSTEM

The propeller order system, circuit M, is used to transmit the desired changes in the number of propeller revolutions from the pilot house or central control station to the enginerooms. The system provides a method of transmitting SMALL changes in speed to the throttle stations. As previously stated, units of the propeller order indicating system are often combined with units of the engine order indicating system in the conning stations.

A representative propeller order system installed in a large ship is illustrated by the block diagram in figure 11-7. The system consists of a propeller order indicator-transmitter installed in the pilot house or central control station and in throttle station 1. A single indicator is installed in throttle stations 2, 3, and 4. The control engineroom repeats the orders back to the conning station.

A propeller order is originated at the conning station by turning the operating knobs of the indicator-transmitter until the selected digits are indicated in the transmitter sections of the three windows provided in the unit cover. The



FIREROOM
1
1MB
2MB
OPEN BRIDGE
2MB
1MB
PILOT HOUSE
2MB
1MB
TRANSFER
SW # 10
1-SEC CONN
2-OFF
TRANSFER
SW # 1
1-OPEN BRIDGE
2-PILOT HOUSE
1MB
2MB
ACO SW. # 7
1-FIREROOM # 1
2-OFF
3-FIREROOM # 2
4-BOTH
TRANSFER SW. # 6
1-ENGINE ROOM # 1
2-NORMAL
3-ENGINE ROOM # 2
TRANSFER SW. # 5
1-ENGINE ROOM # 1
2-NORMAL
3-ENGINE ROOM # 2

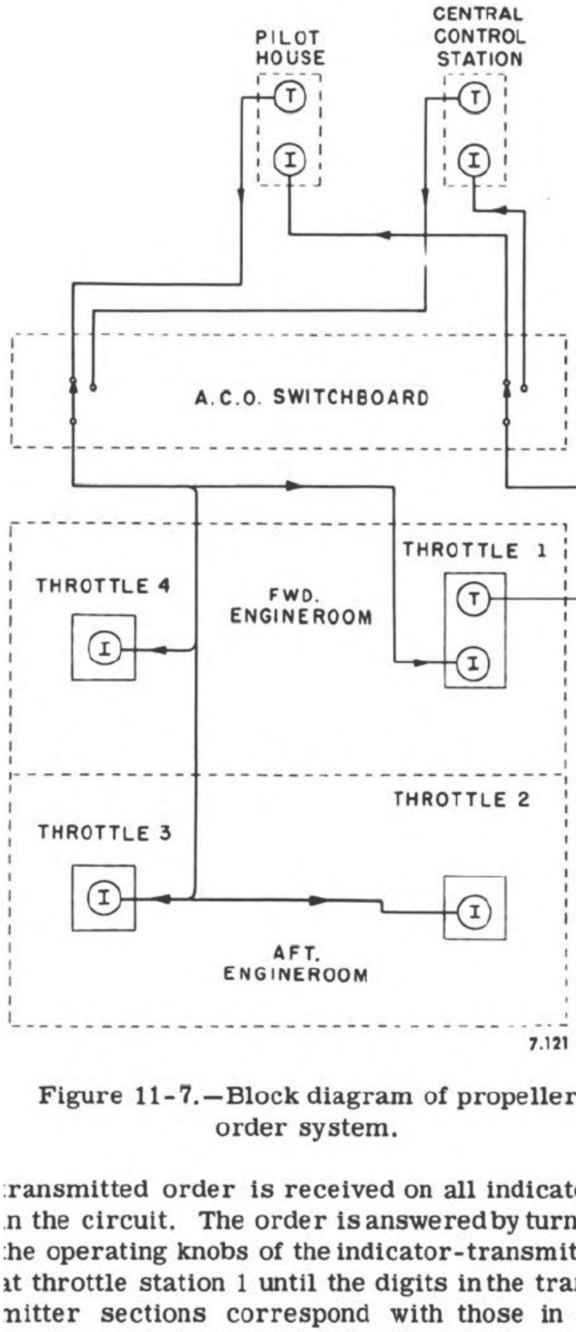


Figure 11-7.—Block diagram of propeller order system.

transmitted order is received on all indicators in the circuit. The order is answered by turning the operating knobs of the indicator-transmitter at throttle station 1 until the digits in the transmitter sections correspond with those in the indicator sections of the three windows. The reply is received at the propeller order indicator-transmitter at the conning station that originated the order. Thus, the conning station is assured that the transmitted order has been correctly received and interpreted.

A selector switch is installed on the ACO switchboard for selecting the indicator-transmitter to control the circuit and a cutout switch is provided at the engineroom unit.

PROPELLER ORDER INDICATOR-TRANSMITTER

The propeller order indicator-transmitter installed in each conning station and in throttle station 1 (fig. 11-7) is used to transmit orders relative to propeller speed and to receive acknowledgement of these orders.

The unit consists of three 23TR6 synchro receivers and three 37TX6 synchro transmitters indicating on six circular dials marked 0 through 9. The transmitters and receivers with the associated dials are mounted on individual baseplates to form three complete and identical indicator-transmitter subassemblies enclosed in a metal case.

The subassemblies are mounted in the case so that the three indicator dials are directly above the three transmitter dials, each showing one numeral through its associated window in the cover (fig. 11-8). The numerals form a 3-digit number (units, tens, hundreds) for the indicators and transmitters respectively. The dials, which are rotating disks, are provided with segregated digit control so that any desired number from 000 to 999 can be set on the transmitters manually by external operating knobs.

Each indicator dial is secured through a dial coupler to the shaft of a 23TR6 synchro receiver and indicates the reply from the engineroom

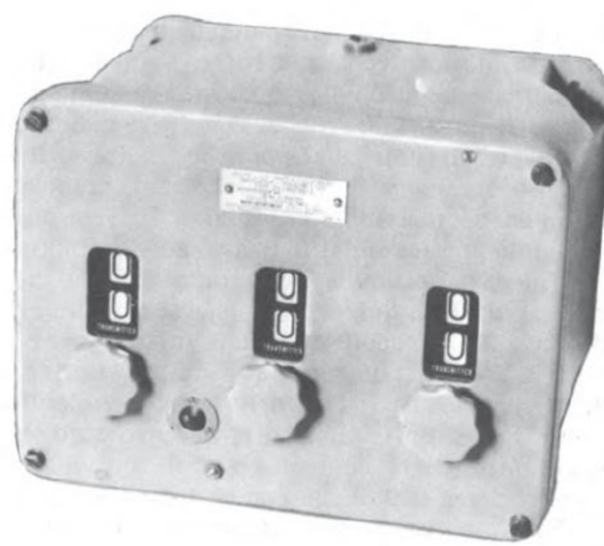


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Figure 11-8.—Propeller order indicator-transmitter.

unit by matching the transmitted order on the associated dial.

Each transmitter dial is secured through a dial coupler to the shaft of a 37TX6 synchro transmitter. The dial is positioned by an operating knob connected through a clutch assembly to the transmitter shaft and indicates the transmitted order on the associated dial. A detent wheel secured to each transmitter shaft actuates a microswitch through a roller and lever arm to close the alarm bell circuit when the transmitter operating knob is moved. This action causes a bell to ring on the indicator unit.

A pushswitch connected in parallel with the microswitch is used for manual signaling to the indicator units. The pushswitch, when operated, causes bells to ring on the indicator units. A buzzer for the ringing circuit is located externally between the port and starboard bells for the engine order circuit. The buzzer sounds an audible signal when the reply is received from the transmitter units.

Dial illumination is provided in the conning station units by three 6-volt lamps located between the receiver and transmitter in each subassembly. The dial lamp circuit is supplied from a 115/6-volt transformer, and the intensity of illumination is controlled by a dimmer knob that operates a rheostat (fig. 11-9).

PROPELLER ORDER INDICATOR

The propeller order indicators installed at throttle stations 2, 3, and 4 (fig. 11-7) are used to indicate the propeller orders. The unit consists of three 23TR6 synchro receivers indicating on three circular dials marked 0 through 9. The receivers with the associated dials are mounted on individual baseplates to form three complete and identical indicator subassemblies.

The subassembles are mounted in the case so that each indicator dial shows one numeral through its associated window in the cover to form a 3-digit number. The dials, similar to those previously described for the propeller order indicator-transmitter, are provided with segregated digit control so that any desired number from 000 to 999 can be indicated.

Each indicator dial is secured directly to the shaft of a 23TR6 synchro receiver and indicates the transmitted order from the conning station (fig. 11-10). A bell on this unit rings each time the propeller order is changed at the conning station. Dial illumination is not provided.

RUDDER ORDER SYSTEM

The rudder order system, circuit L, is used to transmit the desired rudder orders from the pilot house, and conning stations to the after steering station when the ship is being conned at one station and the rudder(s) controlled from the after steering stations(s). The rudder angle indicator system, circuit N, is used as the repeat-back indicator for the rudder order system. Thus, combined rudder order and rudder angle indicator units are installed at all stations equipped with both units. The rudder order system is associated with the steering emergency signal system, circuit LB, to provide an audible signal for the after steering station to take over the steering control locally.

A representative rudder order system combined with the rudder angle indicator system and the steering emergency signal system in a large ship is illustrated by the block diagram in figure 11-11.

The rudder order system consists of a combined rudder angle-order indicator-transmitter installed in the pilot house and conning stations. This unit is electrically connected to a combined rudder angle-order indicator in the after steering gear room and a rudder angle indicator in throttle station 1.

A rudder order is originated at the conning station by turning the operating knob on the rudder angle-order indicator-transmitter until the transmitter pointer marked 0 indicates the desired order on the dial. The transmitted order is received on the rudder angle-order indicator in the after steering station.

A selector switch is installed on the ACO switchboard for selecting the combined rudder angle-order indicator-transmitter to control the circuit.

The double rudder angle indicator is installed in ships with rudders that are powered by separate machinery but controlled from the same steering wheel or helm.

DOUBLE RUDDER ANGLE-ORDER INDICATOR-TRANSMITTER

The combined double rudder angle-order indicator-transmitter installed in each conning

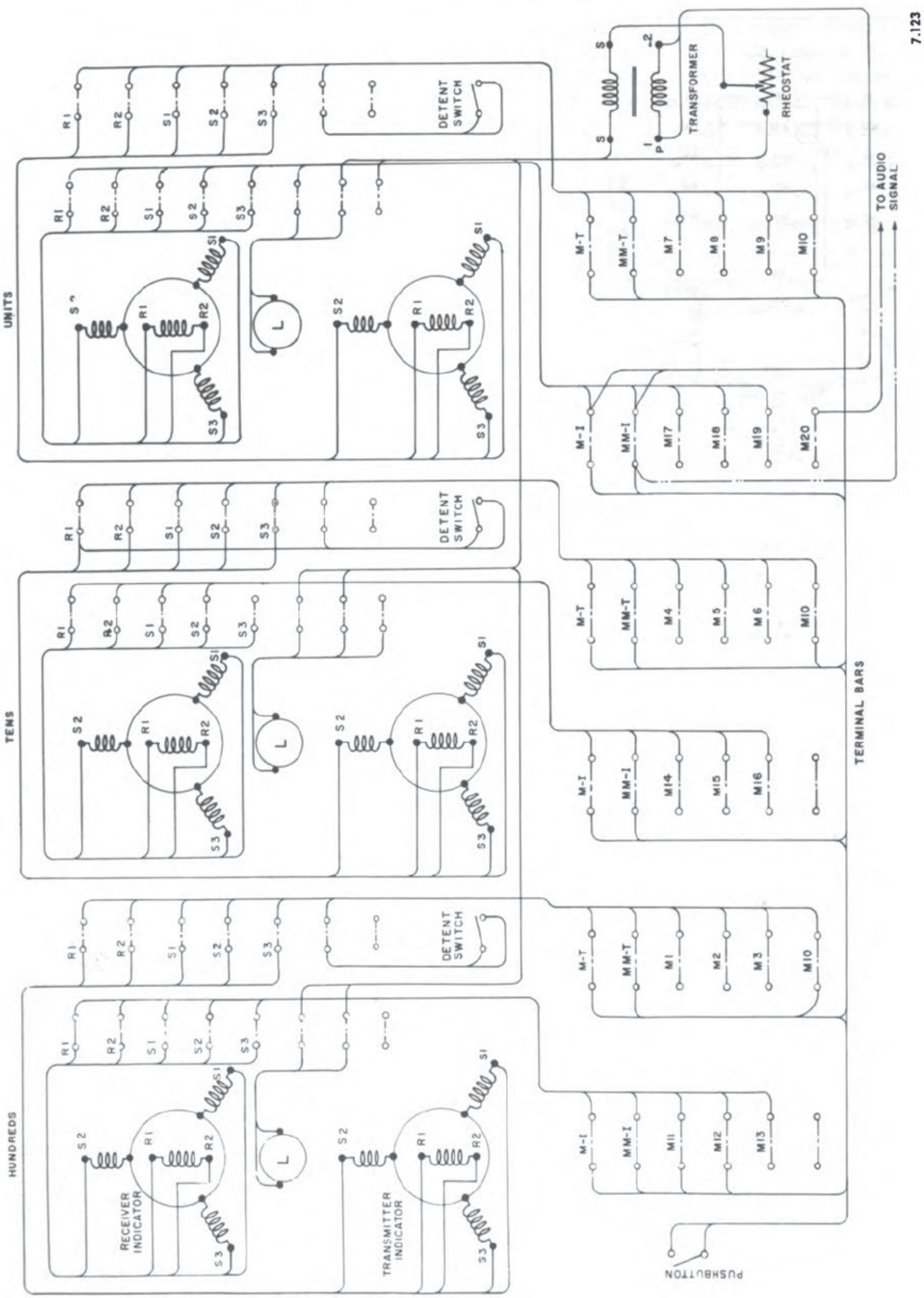

Figure 11-9.—Wiring diagram of propeller order indicator-transmitter.

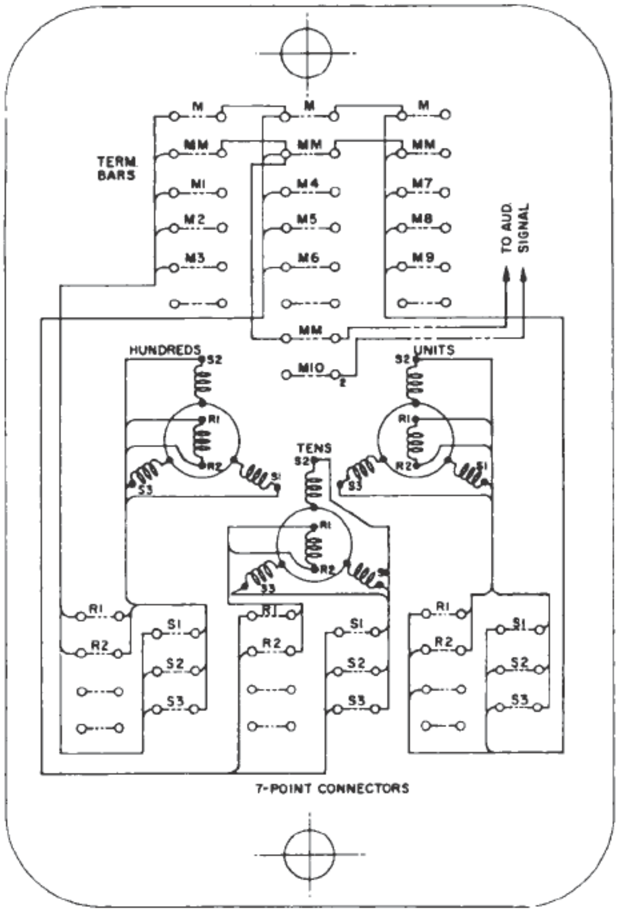

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Figure 11-10.—Wiring diagram of propeller order indicator-transmitter.

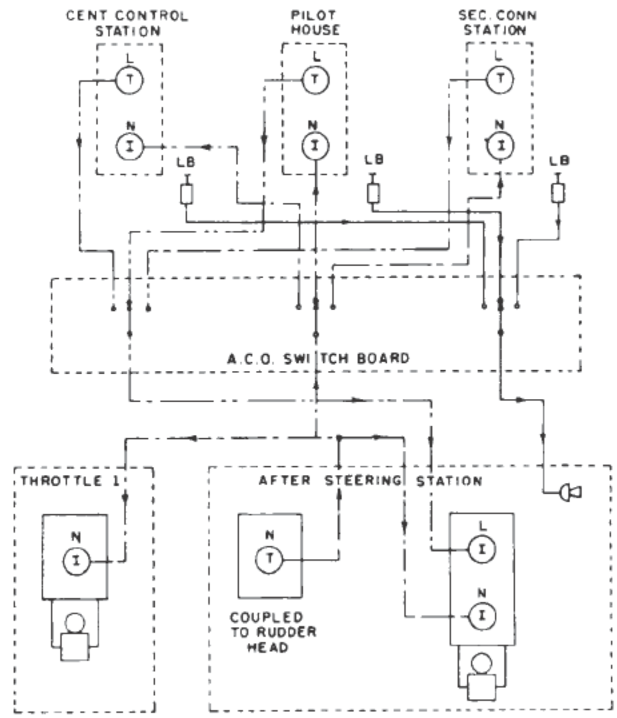

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Figure 11-11.—Block diagram of combined rudder order, rudder angle indicator, and steering emergency signal systems.

station (fig. 11-11) is used to transmit rudder orders and to indicate the actual position of a port and starboard rudder.

The unit consists of a 37TX6 synchro transmitter, a 31TR6 and a 23TR6 synchro receiver indicating on a fixed dial of three concentric revolving pointers. The transmitter and receivers are mounted on brackets to form a complete subassembly (fig. 11-12).

The dial is made of a translucent material having a dull white background with black markings. The markings are graduated in degrees to read from 0° to 40° left rudder, and from 0° to 40° right rudder.

The pointer marked ORD indicates the transmitted rudder orders. It is geared to the shaft of the 37TX6 synchro transmitter and to the operating knob on the cover below the dial. A friction brake in the subassembly holds the order pointer in the selected position.

The pointer marked S is geared to the shaft of the 31TR6 synchro receiver and indicates the actual position of a starboard rudder. This indication is the reply from the rudder angle transmitter (coupled to a starboard rudder head).

The pointer marked P is directly connected to the shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. This indication is the reply from the rudder angle transmitter (coupled to a port rudder head). The reply from the rudder angle transmitters are also indicated on other units throughout the ship.

A pushswitch is provided for manual signaling to the after steering station (fig. 11-13). This pushswitch rings a bell on the unit in the after steering station. The dial is illuminated by 6-volt lamps in the corners of a light panel mounted behind the dial. A pilot light indicates when the system is energized.

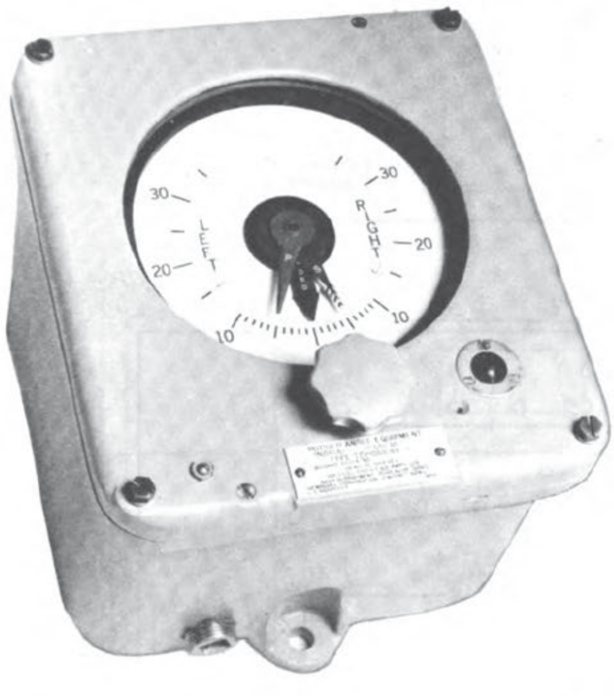

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Figure 11-12.—Double rudder angle-order indicator-transmitter.

DOUBLE RUDDER ANGLE-ORDER INDICATOR

The combined rudder angle-order indicator installed in the after steering station (fig. 11-11) is used to indicate the transmitted order from the conning station and the positions of the rudders as they respond to the trick wheel (emergency helm).

The unit consists of two 31TR6 synchro receivers and a 23TR6 synchro receiver indicating on a fixed dial of three concentric revolving pointers. The three receivers are mounted on brackets to form a complete rudder angle-order indicator assembly.

The pointer O is geared to the shaft of a 31TR6 synchro receiver and indicates the rudder orders transmitted from the conning station. The pointer marked S is geared to the shaft of a 31TR6 synchro receiver and indicates the actual position of a starboard rudder. The pointer marked P is directly attached to the shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. A bell on the unit rings each time the rudder order is changed.

The dial is similar to that of the combined double rudder angle-order indicator-transmitter (fig. 11-12). Dial illumination is provided by 6-volt lamps located in the corners of a light-conducting panel mounted behind the dial. The dial lamp circuit is supplied from a transformer and the intensity of illumination is controlled by a rheostat (fig. 11-14).

RUDDER ANGLE INDICATOR SYSTEM

The rudder angle indicator system, circuit N, is used to transmit indications of the actual position of the rudder to the after steering station, conning stations, throttle stations and other remote positions throughout the ship. The rudder angle indicator system (fig. 11-11) consists of a rudder angle transmitter(s) coupled mechanically to the rudder head(s) in the after steering station(s). For simplicity, only one rudder angle transmitter is shown. The unit is electrically connected to a combined rudder angle-order indicator-transmitter in each conning station, a combined rudder angle-order indicator in the after steering stations, and double rudder angle indicators at other stations.

When the position of the rudder is changed to correspond with the transmitted order from the conning station (in emergencies) or from the conning helm or steering wheel (normal), the rudder angle transmitter transmits the angular position of the rudder to the rudder angle indicators.

RUDDER ANGLE TRANSMITTER

The rudder angle transmitter coupled to the rudder head in the after steering station (fig. 11-11) is used to transmit the actual position of the rudder to indicators at the conning stations, after steering station, and other stations.

The unit consists of a 37TX6 synchro transmitter enclosed in a metal case designed for bulkhead mounting (fig. 11-15). The shaft of the transmitter is geared to a lever arm that is mechanically linked to the rudder by couplings. The gear ratio between the input shaft and the transmitter shaft is 4 to 1, so that a 4° movement of the transmitter shaft equals 1° on the input shaft. As previously stated, the

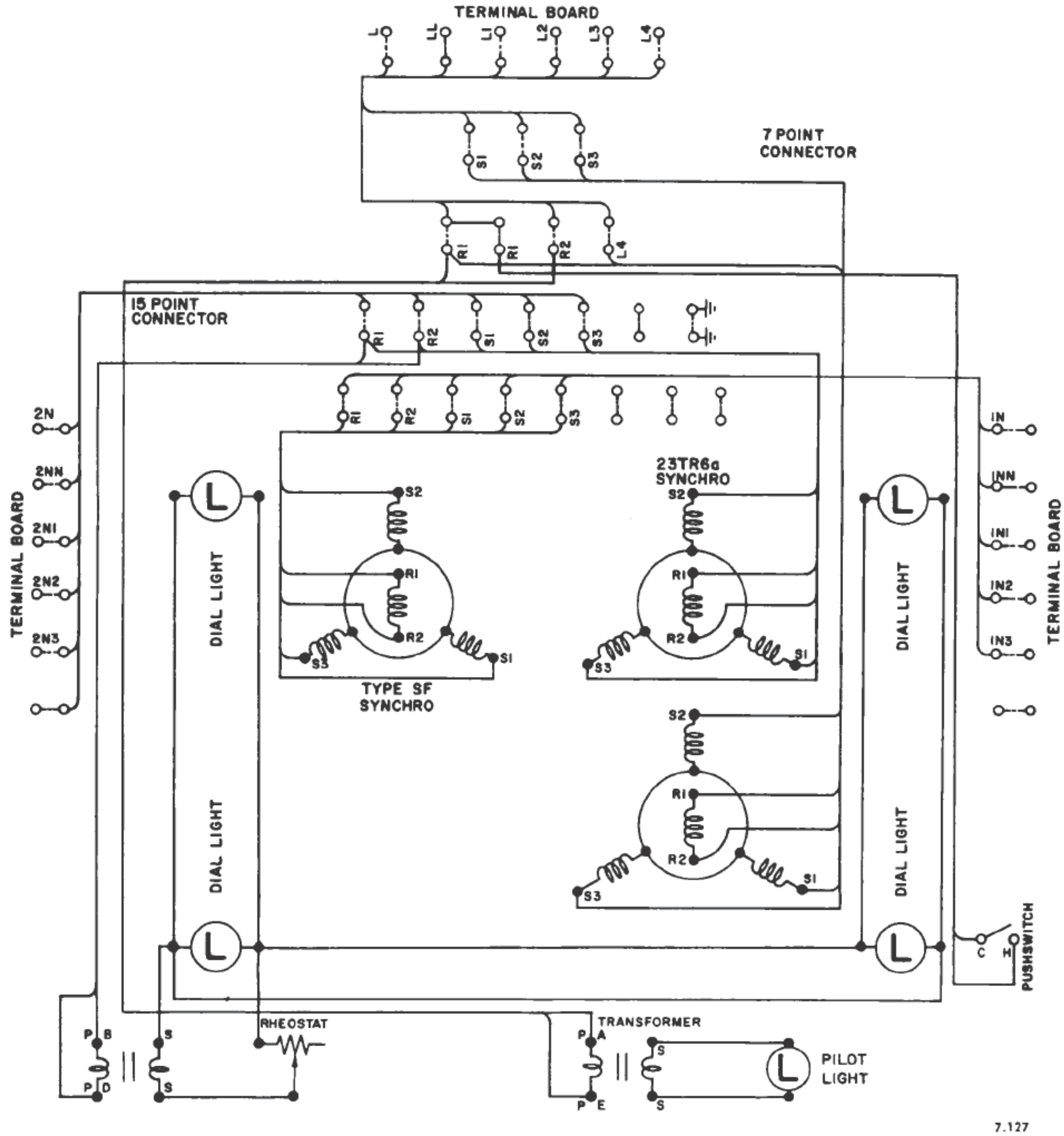

Figure 11-13.—Wiring diagram of double rudder angle-order indicator-transmitter.

transmitter is connected electrically to indicators throughout the ship.

The wiring diagram of the rudder angle transmitter is illustrated in figure 11-16.

DOUBLE RUDDER ANGLE INDICATOR

The double rudder angle indicator installed in throttle station 1 (fig. 11-11) is used to

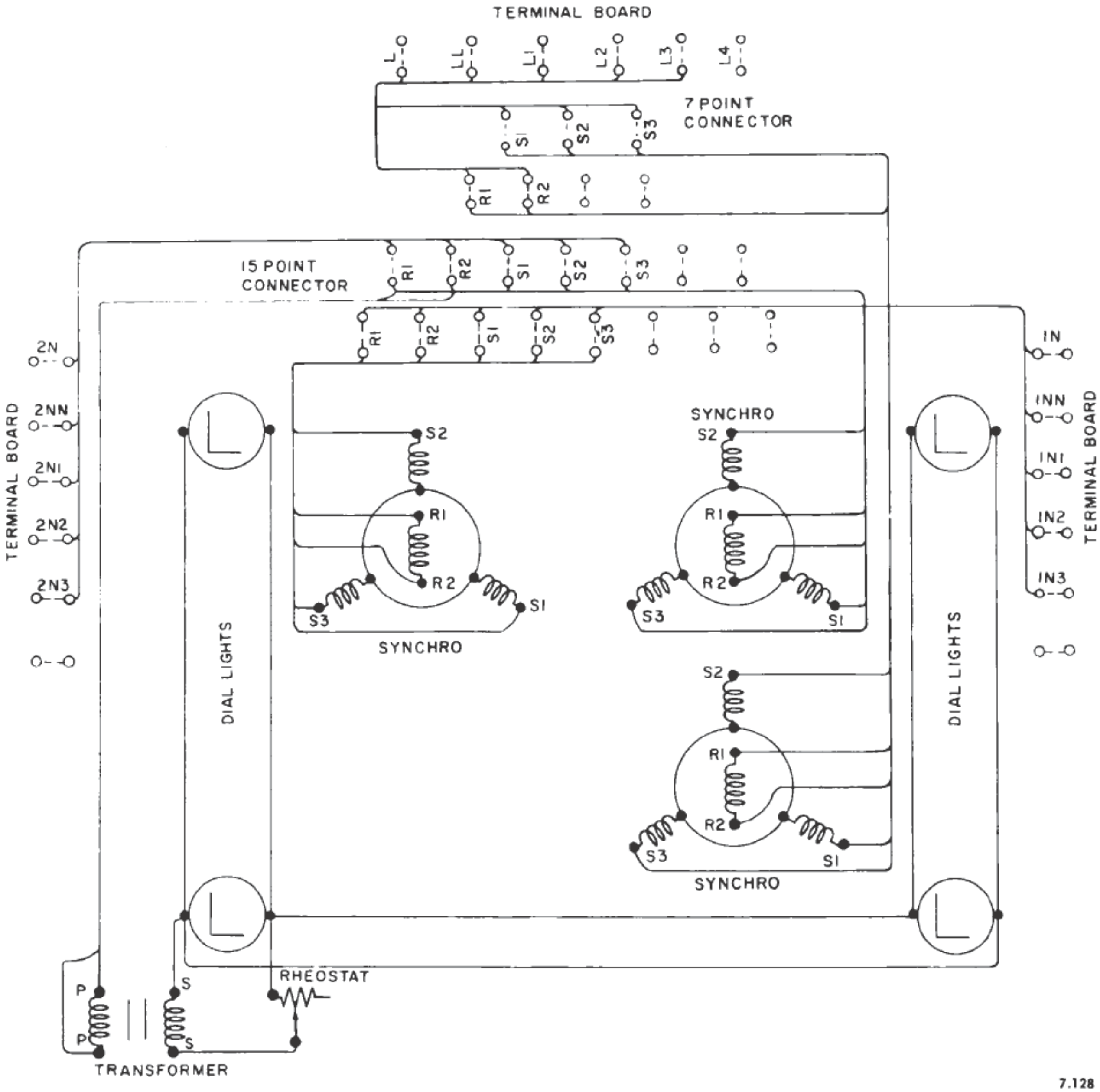

Figure 11-14.—Wiring diagram of rudder order-double rudder angle indicator.

indicate the actual positions of a starboard and port rudder.

The unit consists of a 3F and a 23TR6 synchro receiver (fig. 11-17). The receivers are mounted on brackets to form a complete double rudder angle indicator subassembly.

The dial is similar to that of the combined rudder angle-order indicator-transmitter (fig. 11-12).

The pointer marked S is geared to the shaft of the 3F synchro receiver and indicates the actual position of a starboard rudder. The pointer marked P is directly attached to the

Figure 11-15.—Rudder angle transmitter.

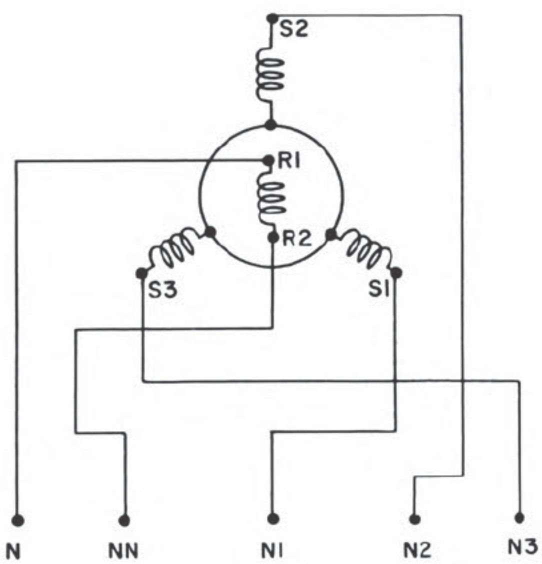

Figure 11-16.—Wiring diagram of rudder angle transmitter.

shaft of the 23TR6 synchro receiver and indicates the actual position of a port rudder. The unit may or may not be provided with dial illumination.

STEERING EMERGENCY SIGNAL SYSTEM

The steering emergency signal system, circuit LB, provides a signal from the conning station to the after steering station for shifting

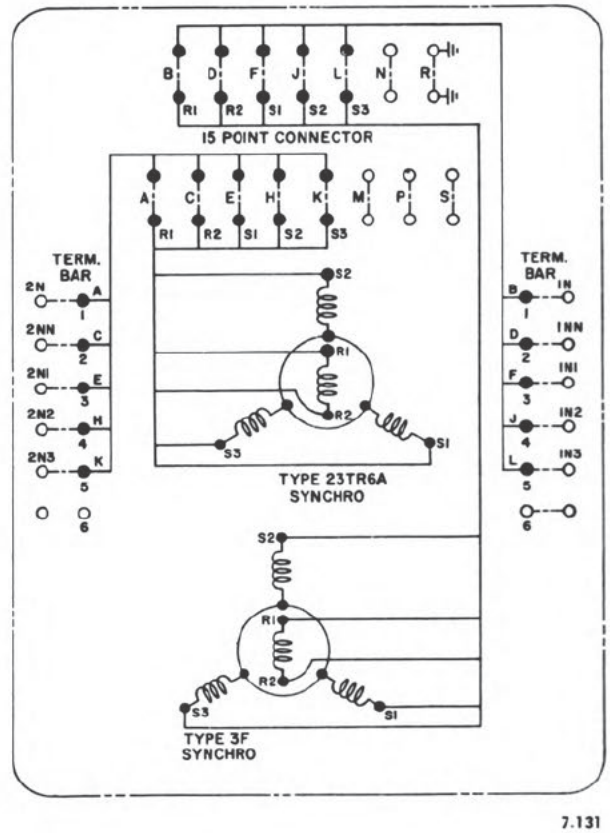

Figure 11-17.—Wiring diagram of double rudder angle indicator.

the steering control to the trick wheel in the steering gear room.

The steering emergency signal system (fig. 11-11) consists of a contact maker installed adjacent to the combined rudder angle-order indicator-transmitter in the pilot house, and conning stations. These contact makers are electrically connected to a siren in the after steering station.

When steering control is lost at the conning station, the contact maker is manually operated to complete the circuit to the siren in the after steering station. This signal is an emergency warning to the steering gear room to take over the steering control locally.

SHIP CONTROL AND STEERING CONTROL CONSOLES

Ship control and steering control consoles are normally installed in the pilot house and

serve as a direct method of controlling the ship. These consoles concentrate in one location many of the interior communications units formerly scattered in several locations about the bridge. The units are combined in two consoles which usually weigh less and require less space than the same units installed separately. The components of the consoles are mounted so that they are easily visible and accessible to the personnel concerned with the control of the ship.

SHIP CONTROL CONSOLE

The ship control console (fig. 11-18) consists of the (1) engine order section, (2) speed light section, and (3) propeller order section.

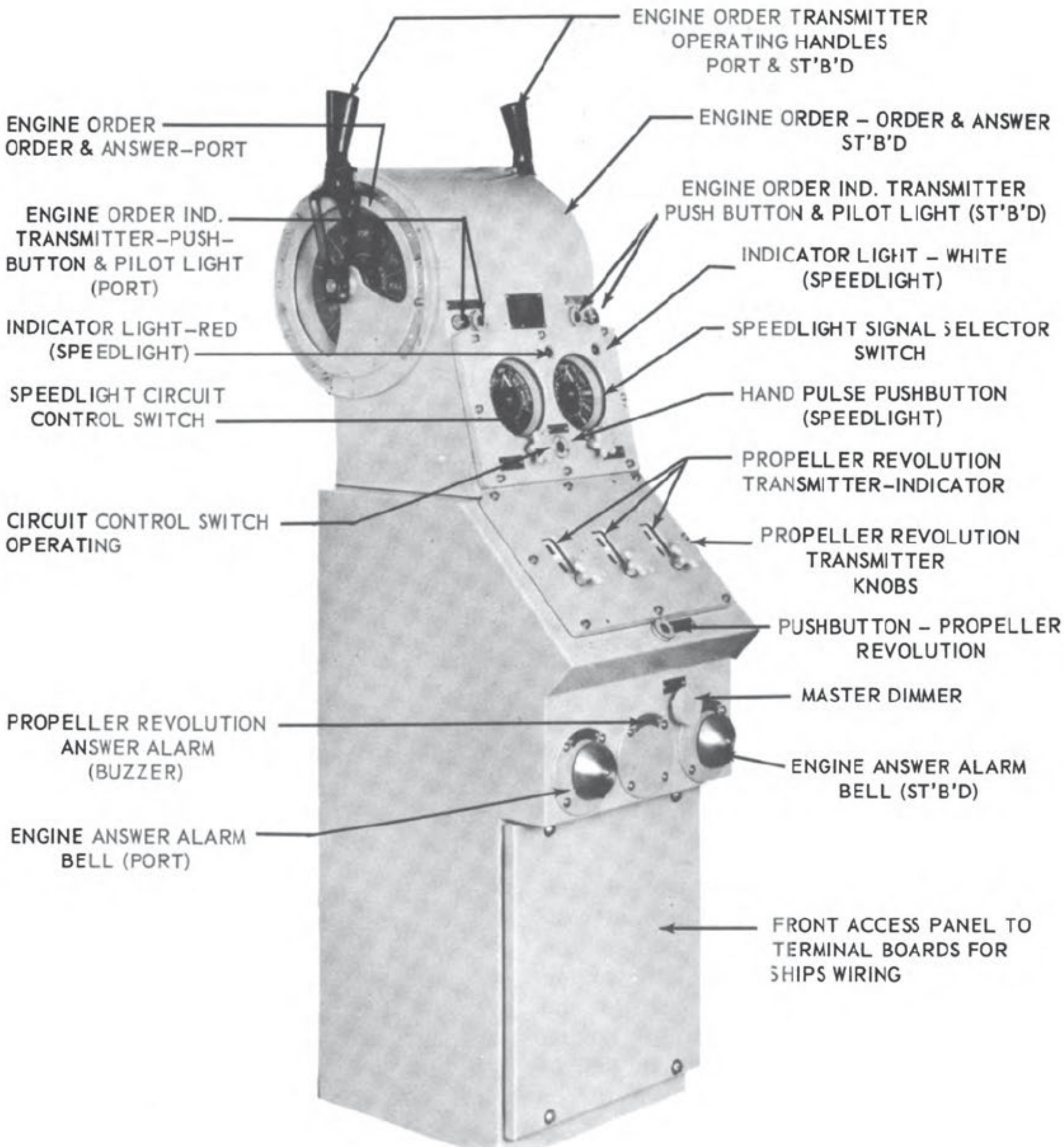

Figure 11-18.—Ship control console.

The ENGINE ORDER SECTION contains the port and starboard engine order indicator-transmitters with the associated pilot lights and ringing pushswitches. When the operating handles on this section are manually set to the desired order, the synchro transmitters which are geared to these handles, transmit the angular positions to the synchro receivers in the engineroom indicator-transmitters. The pointers on the receivers will indicate the same position as the transmitters. A repeat-back is incorporated in the system to enable the engineroom operator to acknowledge the received orders. The repeat-back system is the same as the order system, except the synchro transmitters are in the engineroom indicator-transmitters and the synchro receivers are in the engine order section of the pilot house console.

Each time an operating handle is moved from one order to another a switch is actuated which rings bells at both the transmitters and receivers. The pushswitches in the engine order section of this console are connected in parallel with the switches which operate when the handles are moved, and are for the purpose of allowing the operator to call attention to the engineroom before he gives an order. The pilot lights in this section indicate that the circuit is energized.

The SPEED LIGHT SECTION is contained in the same enclosure. It consists of an internal subassembly containing two rotary switches for controlling the ship's speed and aircraft warning lights. Each switch is equipped with its proper dial, pointer, and operating knob. Two pilot lights, one marked W and the other marked R, indicate when the white or red lights are energized. A pushswitch is provided to actuate the "hand pulse" circuit.

The PROPELLER ORDER SECTION contains the propeller order indicator-transmitter with the associated ringing pushswitch. This section is operated in the same manner as the engine order section, except that it transmits and receives propeller orders instead of engine orders, and is operated by knobs in lieu of handles.

A panel directly below the propeller order section contains two bells, one each for the port and starboard engine order indicator-transmitters; a buzzer for the propeller order indicator-transmitter; and a master dimmer for controlling the intensity of illumination on the dials.

STEERING CONTROL CONSOLE

The steering control console (fig. 11-19) is used in conjunction with the ship control console. It consists of units such as the rudder angle-order indicator-transmitter, helm angle indicator, steering transmitter, ship's course indicator, course-to-steer-indicator, magnetic compass repeater, and steering emergency switch.

The RUDDER ANGLE ORDER INDICATOR-TRANSMITTER consists of a 37TX6 synchro transmitter, and a 23TR6 and a 31TR6 synchro receiver, indicating on a fixed dial by three concentric revolving pointers. The synchro transmitter, connected to the pointer marked 0, is normally operated by a knob on the console panel. The 23TR6 synchro receiver is directly connected to the pointer marked P, and the 31TR6 synchro receiver is connected through gears to the pointer marked S.

When the operating knob is set (under emergency conditions) to the desired position of the rudder on the dial, the synchro transmitter transmits this angular position to the synchro receiver in the rudder angle-order indicator in the steering gear room. The repeat-back is the rudder angle indicator system. The synchro transmitters of this system, which are geared to the rudder heads located in the after steering stations, are electrically connected to the synchro receivers in the rudder angle-order indicator-transmitter unit of the steering control console, and in rudder angle indicator units at other required stations. The pushswitch, associated with the rudder angle-order indicator-transmitter of the steering control console, operates a bell in the steering gear room to call attention to a change of orders.

An emergency rudder angle indicator system has been added to the steering control system on all the latest large ships. The emergency system consists of a transmitter, mechanical linkage, and selector switch. The transmitter is of the same type as that used in the normal system. This transmitter is located in a compartment above the after steering station and connected to the rudder head by a mechanical linkage. The selector switch located in the pilot

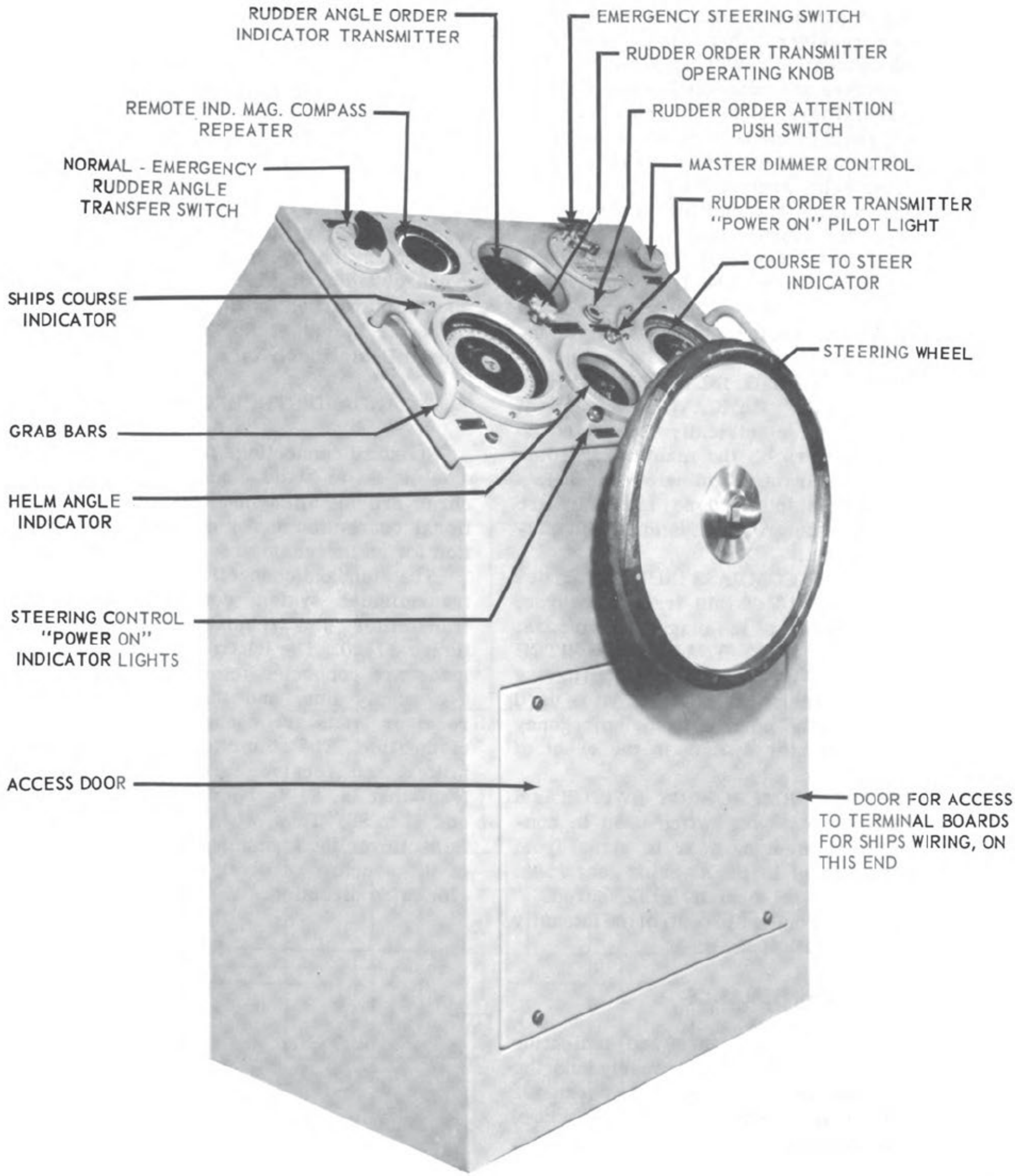

Figure 11-19.—Steering control console.

house energizes the emergency rudder angle indicating system whenever it is required.

The HELM ANGLE INDICATOR consists of two synchro receivers, indicating on a fixed dial by two concentric revolving pointers. The synchro receivers are connected electrically to synchro transmitters on the steering gear and indicate the angle of the helm as received from the steering control transmitter in the console. A mechanical helm angle indicator, geared to the steering control transmitter is sometimes used in lieu of the synchro type.

The STEERING CONTROL TRANSMITTER, actuated by the steering wheel, is electrically connected to a synchro receiver mounted on each steering gear mechanical differential control box (port or starboard).

The SHIP'S COURSE INDICATOR and the COURSE-TO-STEER INDICATOR consist of synchro receivers electrically connected to synchro transmitters on the master gyrocompass. These indicators indicate own ship's course and own ship's course inputs to fire control systems, electronics systems, and navigational equipment.

The MAGNETIC COMPASS INDICATOR, described in chapter 13 of this training course, indicates the reading of the magnetic compass.

The RUDDER ANGLE TRANSFER SWITCH is a standard Navy-type JR rotary switch having a normal and an emergency position. It is used to transfer from the normal to the emergency rudder angle indicator system in the event of power failure.

The STEERING EMERGENCY SWITCH is a standard Navy-type on-off switch used in conjunction with the steering gear to signal from the conning stations to the steering gear room that a steering control casualty has occured.

A dimmer is provided to control the intensity of illumination on all of the dials.

MAINTENANCE

If the ship control order and indicating equipment does not function properly and the cause is not immediately apparent, check for failure of the power supply, blown fuses, burned out dial illumination, and defective wiring, before starting a detailed examination of the circuit units and parts of the equipment. Some faults such as burned out lamps, rheostats, shorted transformers, or wiring can often be located by sight or smell. Check for smoke or odor of burned or overheated parts.

Troubleshooting of electrical circuits and components is readily accomplished by following standard procedures for circuit tracing to isolate the fault. Do not attempt to disassemble the unit until all signal and power sources have been checked and the trouble has been definitely located on the unit. As previously stated, the units comprising the ship control order and indicating systems operate on a standard synchro transmission system. Detailed information concerning the operation and maintenance of synchros is contained in the manufacturer's manual furnished with the equipment, Navy Ordnance Pamphlet No. 1303, and the training course *Basic Electricity.*

STANDARD SYNCHRO CONNECTIONS

Standard connections for synchros have been established to avoid confusion when many synchros are installed in a system. The conventional connection is for counterclockwise rotation for an increasing reading.

The standard connections of a simple synchro transmission system consisting of a synchro transmitter and receiver are illustrated in figure 11-20. The R1 transmitter and receiver leads are connected to one side of the 115-volt a-c supply line, and the R2 transmitter and receiver leads are connected to the other side of the line. The stator leads of both the transmitter and receiver are connected lead for lead—that is, S1 is connected to S1, S2 to S2, and S3 to S3. Thus, when an increasing reading is sent over the transmission system, the rotor of the synchro receiver will turn in a counterclockwise direction.

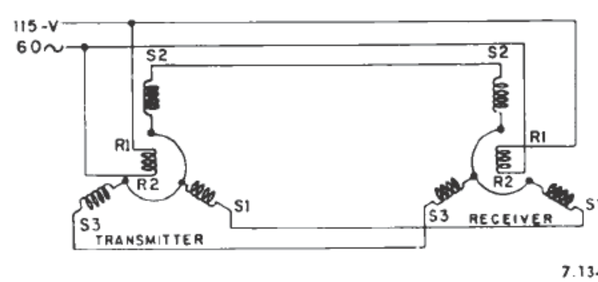

Figure 11-20.—Simple synchro transmission system.

When it is desired that the shaft of the synchro receiver turn clockwise for an increasing reading, the R1 transmitter and receiver leads are connected to one side of the a-c supply, and the R2 transmitter and receiver leads are connected to the other side as before. However, the S1 transmitter lead is now connected to the S3 receiver lead, the S2 transmitter lead to the S2 receiver lead, and the S3 transmitter lead to the S1 receiver lead.

The standard connections of a synchro transmitter to two independent synchro receivers through a rotary switch is illustrated by the wiring diagram in figure 11-21.

SETTING SYNCHROS

In any synchro system that is expected to operate with any degree of accuracy, it is most important that the synchros are electrically zeroed. The methods of zeroing synchros include the use of a voltmeter, neon lamps, two lamps and a headset, and other synchros in the system. However, the most accurate method of setting both synchro transmitters and receivers is obtained by using a voltmeter as illustrated in figure 11-22.

For a synchro to be in a position of electrical zero, the voltage between the S1 and S3 leads must be zero and the phase of the voltage

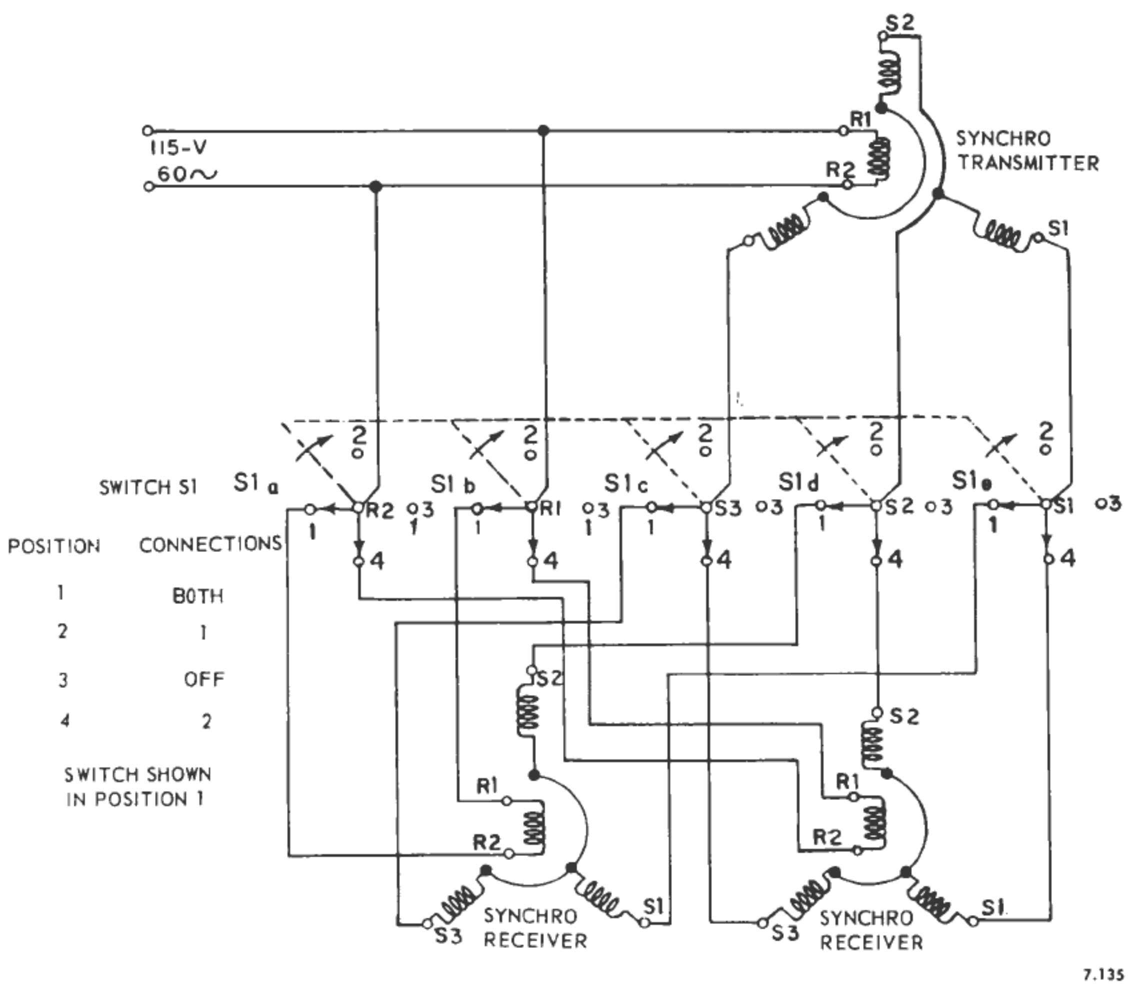

Figure 11-21.—Connections of synchro transmitter and two independent synchro receivers through a rotary switch.

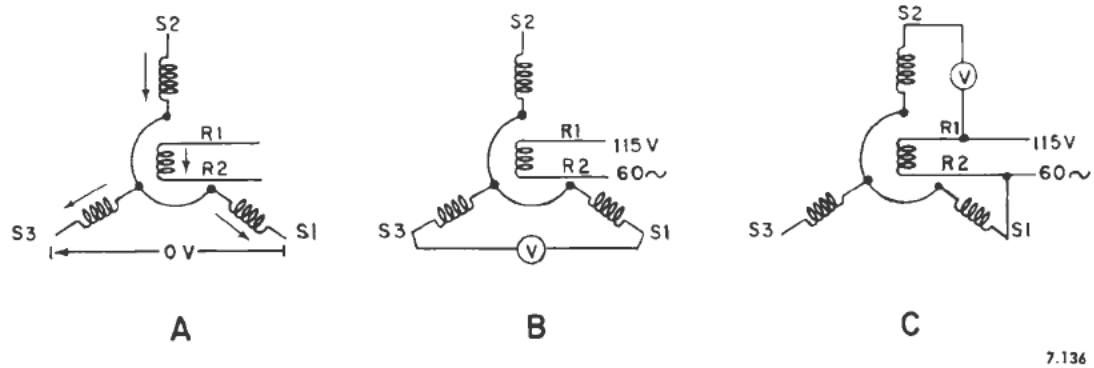

Figure 11-22.—Zeroing synchros.

at S2 must be the same as the phase of the voltage at R1 (fig. 11-22, A). Connect a voltmeter across the S1 and S3 leads (fig. 11-22, B) and rotate the energized rotor until a zero reading is obtained. However, remember that there are two rotor positions (0° to 180°) where a zero reading will be obtained on the voltmeter. In order to locate the proper zero position, it is necessary to determine if the phase of S2 is the same as that of R1. To determine this phase relation, connect a jumper from S1 to the R2 leads and a voltmeter across the S2 and R1 leads (fig. 11-22, C). When the polarity relationship is correct, the voltmeter will read LESS (115v - 78v = 37v) than the line voltage. If the voltmeter reading is greater (115v + 78v = 193v) than the line voltage, then the rotor must be rotated 180 degrees. When the proper phase relationship has been ascertained, connect the circuit again as in figure 11-22, B, and readjust the rotor for a zero voltage reading across leads S1 and S3.

If for any reason, it is necessary to apply an external voltage to the stator windings for any length of time, some method of obtaining a maximum of 78 volts must be used. This can be accomplished by using a transformer, autotransformer, variac, or dropping resistor.

QUIZ

1. Name three components that may comprise a unit of the ship control order and indicating system.
2. Name the two circuits that are provided for the starboard and port engines in the engine order system.
3. What feature is provided in the indicator-transmitter units located at the throttle stations to warn the operator when an order is answered incorrectly?
4. Where is the main engine control located?
5. What are throttle stations 1 and 4 called?
6. Where are throttle stations 1 and 4 located?
7. What are throttle stations 2 and 3 called?
8. Where are transmitted engine orders received?
9. How are the transmitted orders acknowledged at the following throttle stations?
10. Where is the reply from the following throttle station received?
11. Where is the reply from the leading throttle stations received?
12. Where are the units located that ring a bell each time an order is originated at the conning station?
13. What unit is frequently combined on one console with the double engine order indicator-transmitter installed in each conning station?
14. Why are two identical indicator-transmitter subassemblies provided in the double engine order indicator-transmitter unit?
15. How are the port and starboard dial markings arranged on the double engine order indicator-transmitter (fig. 11-2) with respect to either transmitter operating handle?
16. What is the purpose of the bells mounted externally on each side of the double engine order indicator-transmitter?

17. What is the function of the double engine order indicator installed in throttle station 1 (fig. 11-1)?

18. What units are energized when transfer switch 1, labeled "engine order indicators and transmitters" (fig. 11-6), is in position 1, marked open bridge?

19. What unit is energized when ACO switch 7, labeled "engine order indicators" (fig. 11-6), is in position 1, marked fireroom 1?

20. What unit is energized when transfer switch 10, labeled "engine order indicator" (fig. 11-6), is in position 1, marked secondary conning station?

21. What is the purpose of the propeller order system?

22. How are transmitter propeller orders acknowledged at throttle station 1 (fig. 11-7)?

23. What is the purpose of the microswitch that is actuated each time the operating knob of the propeller order indicator-transmitter is moved at the conning station?

24. Why are units of the rudder angle indicator system combined with units of the rudder order system at all stations equipped with both units?

25. Where are the transmitted rudder orders from the conning station received?

26. What is indicated by the pointers marked P and S on the combined rudder angle-order indicator-transmitter at the conning station?

27. What is the purpose of the combined rudder angle-order indicator installed in the after steering station?

28. What is the purpose of the rudder angle transmitters coupled to the rudder heads in the after steering station?

29. What is the purpose of the double rudder angle indicator installed in throttle station 1?

30. What is the purpose of the steering emergency signal system?

31. What components comprise the steering emergency signal system?

32. When synchros are connected for standard or conventional operation, what is the direction of rotation for an increasing reading?

33. What two conditions must exist for a synchro to be in a position of electrical zero (fig. 11-22, A)?

34. Name the rotor positions at which a zero reading will be obtained on a voltmeter connected across the S1 and S3 leads (fig. 11-22, B).

35. When the synchro rotor is in the proper 0° position, is the voltmeter reading (fig. 11-22, C) less or greater than the line voltage?

CHAPTER 12

SHIP'S METERING AND INDICATING SYSTEMS

Ship's metering and indicating systems include the shaft propeller revolution indicator systems, wind direction and speed indicator system, salinity indicator system, underwater log system, and many others.

The units comprising the ship's metering and indicating systems are enclosed in splash proof metal cases designed for bulkhead or panel mounting, depending on the stations in which they are located. Windows are provided in the unit covers where required for viewing the dials and counters. The internal subassemblies can be withdrawn individually from the cases to facilitate troubleshooting and repairs.

The incoming ship's cables are brought through watertight terminal tubes into the cases and the leads are connected to terminal strips or female connectors. The leads for the synchros, backing signals, and other components are connected to corresponding terminal strips or male connectors within the cases.

SHAFT REVOLUTION INDICATOR SYSTEM

The shaft revolution indicator system, circuit K, is used to indicate instantaneously and continuously the (1) revolutions per minute, (2) direction of rotation, and (3) total revolutions of the individual propeller shafts. The information is indicated in the enginerooms, pilot house, and other required locations.

The system comprises the (1) synchro-type equipment and (2) magneto-voltmeter-type equipment. The synchro-type equipment is installed in large combatant ships and in many newly constructed small ships. The magneto-voltmeter-type equipment is less complicated and is installed in small ships, such as AMs, AMSs, and many others.

SYNCHRO-TYPE EQUIPMENT

A representative synchro-type shaft revolution indicator system installed in a large ship is illustrated by the block diagram in figure 12-1. The system consists of various transmitters, indicator-transmitters, and indicators. The transmitters for shafts 1 and 4 are installed in boiler operating station 3, and those for shafts 2 and 3 are installed in the after auxiliary machinery room. The transmitters are electrically connected to indicator-transmitters in their respective throttle stations. Indicators are also installed on the gage boards in the associated enginerooms and in the pilot houses as

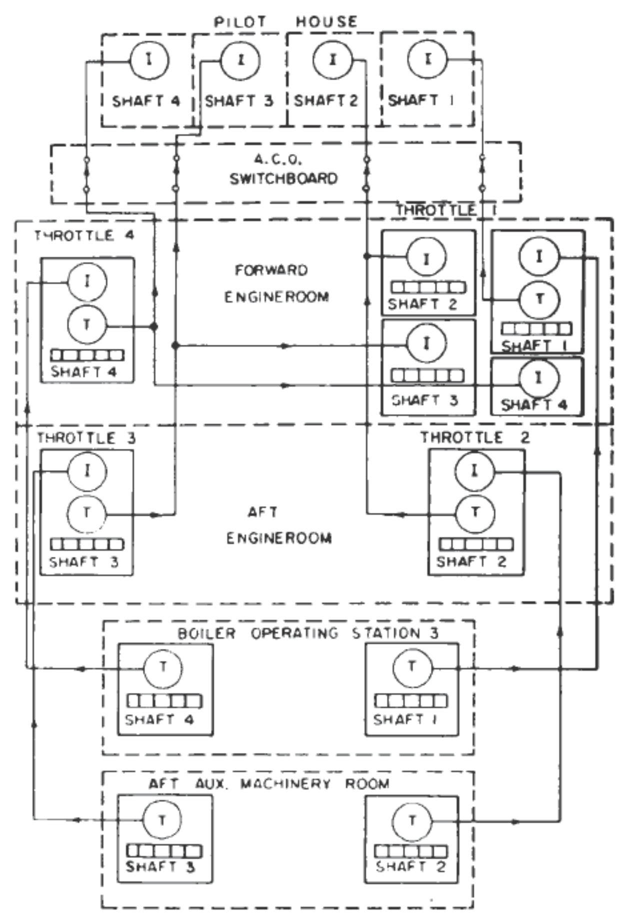

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Figure 12-1.—Block diagram of propeller revolution indicator system.

required by the types of ships. Each indicator is provided with a backing signal lamp which, when lighted, denotes astern rotation of the propeller shaft.

The rotary motions of the propeller shafts are transmitted by the shaft transmitters to the associated indicator-transmitters which convert the received rotary motions into stationary angular synchro displacements. The angular displacements, which are proportional to the speeds of the propeller shafts, are transmitted to indicators located at various stations. The indicators repeat the rpm readings received from the associated indicator-transmitters.

The wiring diagram of a propeller revolution indicator system installed in ships having two propeller shafts is illustrated in figure 12-2. For simplicity, the wiring for only one shaft is shown. The entire system is designed for operation on the ship's single-phase 115-volt 60-cycle power supply.

Transmitter

The transmitter, one for each propeller shaft (fig. 12-1), is used to indicate the revolutions of the propeller shaft and to transmit the speed and direction of rotation of the propeller shaft to the associated indicator-transmitter.

The unit consists of a 5G running synchro transmitter, revolution counter, and contact assembly (fig. 12-3). These components, which are actuated by suitable gearing, are mounted in a watertight housing to form a complete transmitter subassembly. The transmitter is either gear driven from the propeller shaft, or is directly coupled to the end of a stub shaft of the propulsion machinery as required by the particular installation. The synchro transmitter is always driven at one-half the propeller speed in a constant clockwise direction.

A drive worm, cut integral with the shaft 56, meshes with worm gear 12, which is secured to shaft 14. The ratio is such that shaft 14 is driven at exactly one-tenth the propeller speed. The gear 25 is attached to shaft 14 and the links 20 are free to swing on the shaft. The lower ends of links 20 support the swinging shaft 31. The gear 26 is attached to shaft 31. The friction blocks 23 are held in contact with the hubs of gears 25 and 26 by the spring 24. The friction blocks restrain the rotation of the gears 25 and 26 and swing the links assembly, including shaft 31 and gear 26 in the direction of rotation of gear 25. This action engages gear 26 with one of the two gears 27, the selection depending on the direction of rotation of gear 25. The screws 80 limit the angular swing of the links assembly.

The gears 27 are secured to the respective side shafts 35, which also carry gears 29 and 69. These gears are meshed and drive each other alternately, depending on which one of the two gears 27 is engaged with the swinging idler gear 26. It is obvious that gears 29 and 69 rotate in one direction only, irrespective of the direction of propeller shaft rotation, because idler gear 26 reverses rotation each time it swings from side to side. The same is true for gears 28 and 57, because they are mounted on the hubs of gears 29 and 69, respectively. Gear 57 engages gear 58 which is mounted directly on the shaft of the synchro transmitter 37. The overall gear ratio between the transmitter shaft 56, and the shaft of the synchro transmitter is such that the synchro shaft is always driven at one-half the propeller speed in a constant clockwise direction.

The revolution counter 38 which is driven at one-tenth the propeller speed, is driven through helical gears 28, 48, 47, and 30. The reading is directly in terms of propeller revolutions because each revolution of the counter shaft registers a count of ten. The brake shoes 50 prevent the synchro transmitter 37 from driving the counter 38, backward during brief periods of rapid speed reduction.

The contact assembly is actuated by a small insulating block 22, attached to one of the swinging links 20. The block moves up and down as the link swings with reversals of driving rotation. This action moves the center spring contact 44 from the bottom to the top stationary contact 42, and vice versa. The center contact and one of the stationary contacts energize the signal lights in the remote indicator when the propeller shaft rotates in the astern direction.

Indicator-Transmitter

The indicator-transmitter installed in each throttle station (fig. 12-1) is used to convert the running speeds (received from the associated shaft transmitters) into angular synchro displacements which are transmitted to the various indicators.

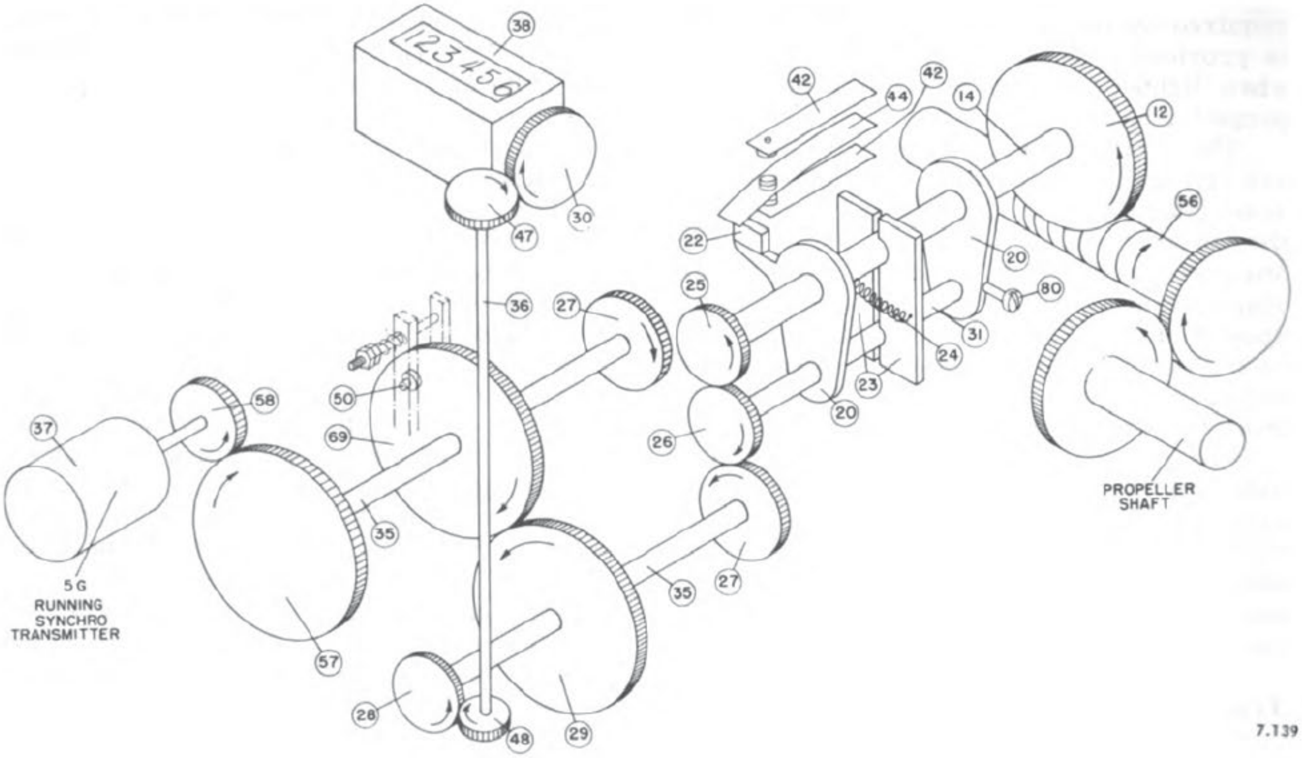


Figure 12-3.—Schematic diagram of transmitter.

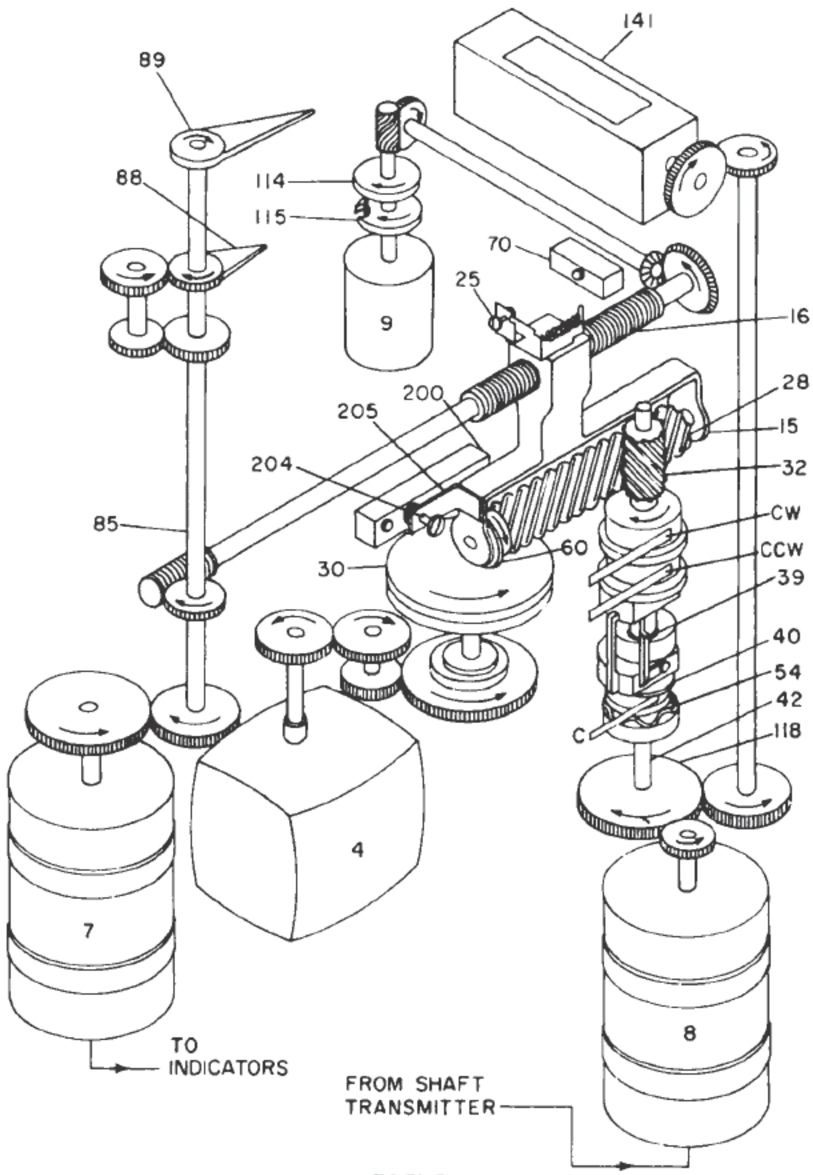
The unit consists of a 31TR6 running synchro receiver, a speed-measuring mechanism, a 5G positioning synchro transmitter, revolution counter, two pointers, a dial, and a backing signal (fig. 12-4). These components and associated gears are mounted on a baseplate to form a complete indicator-transmitter subassembly enclosed in a watertight housing.

The two concentric revolving pointers indicate on a dual-marked fixed-dial the output in rpm of the speed-measuring mechanism. The inner scale, marked for each 100 rpm only, is indexed by the short pointer 88. The outer scale, calibrated from zero to 100 rpm with numerals for each 5 rpm, is indexed by the long pointer 89. The positioning synchro transmitter 7, and pointers 88 and 89 are geared to the friction roller 60, and followup motor 9, so that they all move together in proper relationship to the radius of disk contact which is the actual measure of rpm. The long pointer 89 makes one complete revolution every 100 rpm and the short pointer 88 makes one complete revolution for full scale indication. The relative direction of the speed is indicated by the backing signal indicator which is lighted only when the propeller shaft rotates in the ASTERN direction.

The 31TR6 running synchro receiver 8 is driven electrically by the associated shaft transmitter at a speed exactly one-tenth that of the propeller shaft. The running synchro drives the input shaft of the speed-measuring mechanism through gear 118. The speed-measuring mechanism converts the rotary motions into proportional angular displacements. The running synchro 8 also drives the revolution counter 141 through gears at a speed exactly one-tenth that of the propeller speed. The revolution counter registers the total propeller revolutions directly, irrespective of the direction of rotation.

The 5G positioning synchro transmitter 7 receives the angular displacements from the speed-measuring mechanism and transmits these displacements to the remotely located indicators.

The speed-measuring mechanism (fig. 12-4) is similar in operation to the friction disk and roller assembly described in the chapter on



LEGEND

4 – SYNCHRONOUS MOTOR
7 – POSITIONING SYNCHRO TRANSMITTER
8 – RUNNING SYNCHRO RECEIVER
9 – FOLLOWUP MOTOR
15 – TRAVELING YOKE
16 – LEAD SCREW
25 – SWITCH OPERATING SCREW
28 – HELICAL GEAR
30 – FRICTION DISK
32 – HELICAL GEAR
39 – SLIP RING AND CONTACT ASSEMBLY
40 – HUB ASSEMBLY
42 – INPUT SHAFT
54 – SPRING WASHER
60 – FRICTION ROLLER
70 – LIMIT SWITCH
85 – POINTER SHAFT
88 – INNER POINTER
89 – OUTER POINTER
114 – DRIVEN DISK
115 – DRIVE DISK
118 – INPUT GEAR
141 – MECHANICAL COUNTER
200 – SPEED SIGNAL SWITCH
204 – ACTUATOR SCREW
205 – BRACKET

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Figure 12-4.—Schematic diagram of indicator-transmitter.

basic mechanisms in the training course *I. C. Electrician 3*, NavPers 10555-A. It is an automatic comparison device that is continuously self-adjusting to balance the unknown propeller shaft speed against a known fixed speed. Electrical contacts operate in response to the output of the device and control a followup motor that matches the two speeds.

The unknown speed is the input of the running synchro receiver 8, which is geared to the input shaft 42 of the speed-measuring mechanism through gear 118.

The known speed is provided by the synchronous motor 4, which drives the friction disk 30 through gears at a constant speed. The gearing is such that the disk speed is 16 2/3 rpm for 200 range units and 33 1/3 rpm for 400 range units. The friction disk is held in continuous contact with the friction roller 60, which is integral with the helical gear 28. The friction roller and helical gear are mounted on the traveling yoke 15, which has a total longitudinal motion of approximately 1.10 inches along the radius of the friction disk 30. The yoke is positioned along the disk radius by the lead screw 16, which is driven by the followup motor 9.

The friction roller 60, integral with helical gear 28, drives the helical gear 32, which is mounted on, but free to turn, through a limited range about the input shaft 42. Thus, the helical gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The radius of contact at any given point will determine the drive ratio and speed at which the roller 60, and gears 28 and 32 will rotate.

The speed of helical gear 32 is automatically adjusted to match the speed of the running synchro driven gear 118, by the slipring and contact assembly 39, the upper two sliprings of which are mounted on the hub of gear 32, and are free to turn through a limited range about the input shaft 42. The assembly carries two outside brush contacts CW and CCW, each of which slides on a slipring. The center brush contact C slides on a slipring which is attached to the hub 40 and is secured to the input shaft 42 by the friction thrust washer 54. The contact assembly can be turned in either direction so that one or the other of the outside contacts can mate with the center contact. This action energizes the followup motor 9 and determines its direction of rotation.

When the input gear 118 and the helical gear 32 are running at exactly the same speed, the contacts are open, the followup motor 9 is deenergized, and the indicator pointers 88 and 89 are stationary. However, if the speed of gear 118 changes, the followup motor 9 is energized and drives the lead screw 16, which moves the yoke 15, in or out, depending on the direction of rotation. If the speed of gear 118 is faster than the original balanced speed, the CW contacts close, and if the speed is lower, the CCW contacts close. The contacts will remain closed to energize the followup motor in a correcting direction until the radius of disk contact with roller 60 reaches a new value where the speed of gear 32 is again equal to that of gear 118. At this point the contacts open to deenergize the followup motor.

It is obvious that at zero (rpm) input from the running synchro receiver 8, gear 118, is stationary and that the contacts of the slipring assembly will cause the followup motor 9 to move the lead screw 16, and thus the friction roller 60, toward the center of the friction disk 30. At the exact center, the indicator pointers 88 and 89 should read zero rpm, and the positioning synchro transmitter 7 should be on electrical zero. However, the pointers will not reach the exact scale zero because a limiting switch (not shown in fig. 12-4) deenergizes the synchronous motor 4 at a pointer indication of approximately 1 rpm.

The full scale indication should occur when the point of roller contact is exactly 1 inch from the center of the disk 30. The indicators provide for an overspeed indication of about 10 percent above full scale (1.10 inches disk radius) before the limit switch 70 is actuated.

The indicator-transmitter can be provided with a speed signal switch 200 to continuously energize a remote light or other signal at propeller speeds below a specified value. The signal setting is adjustable from about one-quarter of full speed down to about 5 rpm. As the speed of the propeller shaft decreases from higher values above the switch operating point, the yoke 15, bracket 205, and actuator screw 204, are advanced along the lead screw 16, until the roller and arm of the stationary SPDT switch 200, are lifted by the actuator screw 204. The speed value at which the switch is operated is determined by the height of the actuator screw 204, above the bracket 205. The speed signal

switch is adjusted by turning the actuator screw until the desired operating point is obtained. After the switch has been actuated in decreasing speed direction, it will remain actuated at lower speeds down to zero. Also, when the propeller speed increases, the OFF or release point of the switch will occur at a value slightly above the ON speed value in a decreasing direction because of the operating differential inherent in the micro-switch 200.

Separate terminals 8K and 8KK are provided in the indicator-transmitter unit (fig. 12-2) for the synchronous motor. If the ship is equipped with a special accurately controlled frequency supply, remove the jumpers from terminals 8K and 8KK, and from the controlled frequency supply connected directly to these terminals. Slight deviations from exactly 60 cycles will affect the speed of the synchronous motor, therefore the accuracy of the rpm indicator readings will be affected proportionally.

Indicator with Revolution Counter

Indicators are available in several Navy types for various kinds of service and locations aboard ship. The components that comprise a unit may vary, but the principle of operation is the same. Every indicator contains a synchro receiver, dial, pointer, and backing signal, to provided speed and direction information. In addition to these components, an indicator may be equipped with a revolution counter and synchro receiver with associated gears to indicate the total rpm of the propeller shaft. An indicator used in a dark location contains dial lamps, a red filter, 115/6-volt transformer, and a dimmer rheostat.

The indicator with revolution counter installed in throttle station 1 (fig. 12-1) is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a 3F positioning synchro receiver and an 1F running synchro receiver mounted on a baseplate. A revolving pointer indicates on a dial, the rpm of the associated propeller shaft.

The 3F synchro receiver is driven by the 5G positioning synchro transmitter in the associated indicator-transmitter unit and positions the indicator pointer through gears. The 1F synchro receiver is driven by the associated shaft transmitter and drives the revolution counter through gears. The entire subassembly is enclosed in a case to form a complete indicator unit. A backing signal light in the unit is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the astern direction.

Indicator

The indicator installed in the pilot house (fig. 12-1) is used to indicate the rpm of the associated propeller shaft. The unit consists of a 3F positioning synchro receiver and a revolving pointer that indicates on a dial the rpm of the associated propeller shaft. The 3F synchro receiver is driven by the 5G positioning synchro transmitter in the associated indicator-transmitter unit (fig. 12-2). The indicator is provided with a backing signal that is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the reverse direction.

MAGNETO-VOLTMETER-TYPE EQUIPMENT

The magneto-voltmeter propeller revolution indicating equipment consists of a transmitter of the magneto type geared to each propeller shaft and electrically connected to remotely located indicators of the voltmeter type. The wiring diagram of a representative magneto-voltmeter propeller revolution indicator system is illustrated in figure 12-5. The speed of the propeller shaft is converted by the magneto into a proportional d-c voltage. The indicators receive this voltage and indicate on the associated scales the rpm of the propeller shaft. The magneto-voltmeter indicating equipment is self-energizing and does not require a separate power source for operation.

Transmitter

The magneto transmitter, coupled to the propeller shaft directly or through gears, is used to generate and transmit to the indicators speed, direction, and total number of revolutions of the propeller shaft. The unit consists of a magneto, 1G synchro transmitter, revolution counter, and a unidirectional mechanism (fig. 12-5). These components are mounted on a baseplate to form a complete transmitter subassembly enclosed in a watertight housing.

The magneto is a permanent magnet type of d-c generator which is driven through two bevel gears at a speed proportional to that of the propeller shaft. At an armature speed of 1000 rpm the output of the magneto is 3 volts. The permanent magnet field is stationary, and the armature rotates. The armature winding consists of a distributed closed circuit winding which is connected to a multisegment commutator. The segments and brushes are usually gold to prevent corrosion and to maintain satisfactory conductivity. The polarity of the generated voltage changes with reversal of armature rotation. For this reason, the output of the magneto is fed through the reversing contacts of a SPDT relay to the terminals marked "+" and "-". Whenever the propeller shaft rotates in the reverse direction, the relay coil is energized by a SPDT switch which is automatically actuated by a swivel arm in the unidirectional

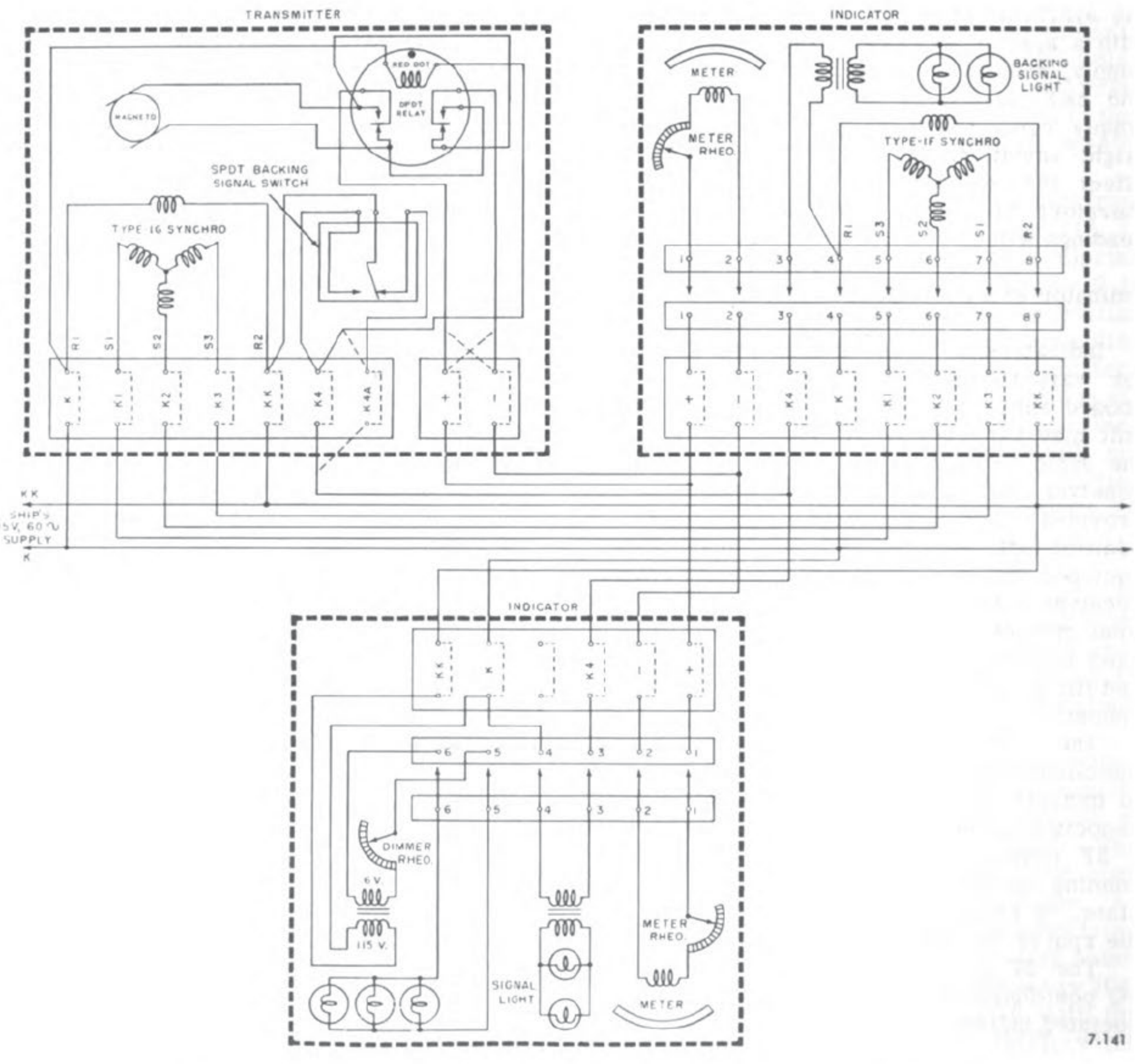

Figure 12-5.—Wiring diagram of magneto-voltmeter propeller revolution indicator system.

mechanism. This action causes the relay contacts to transpose the magneto connections to the terminal strip so that the output of the transmitter retains uniform polarity irrespective of the direction in which it is driven. The SPDT switch also transmits the direction of rotation because it simultaneously energizes a backing signal in the remotely located indicators.

The REVOLUTION COUNTER registers the total number of propeller revolutions locally at the magneto transmitter, and the 1G synchro transmitter transmits these revolutions to the 1F synchro receiver which drives the associated revolution counter in the remote indicator. The revolution counter and the 1G synchro transmitter are mechanically driven at one-tenth the propeller speed through appropriate gearing by the input shaft.

The UNIDIRECTIONAL MECHANISM, a gear changing device, is incorporated in the gear train that drives the revolution counter and the 1G synchro transmitter in order to add the propeller revolutions in both the ahead and astern directions of the propeller shaft. The mechanism (fig. 12-6) consists of a friction disk, two swivel-mounted idler gears, and a spring lever. The two swivel-mounted idler gears are located between the driving and driven gears so that the driven gear is alternately driven by either the upper or lower idler gear, as determined by the position of the swivel arm.

The spring lever is attached to the swivel arm, the lower end of which is slotted and engages a crank pin located off-center on the friction disk. The friction disk presses against the driving gear and rotates with it until the crank pin reaches the lower extremity of the slot in the lever where it is restrained. When the driving gear reverses direction of rotation, the disk rotates with it until the crank pin reaches the upper extremity of the slot in the lever where it is again restrained. Thus, the rotary motion of the friction disk simultaneously rocks the swivel arm causing a transposition of the upper and lower idler gears with respect to the driven gear. This action automatically drives the driven gear counterclockwise irrespective of the direction of rotation of the driving gear.

Indicator with Revolution Counter

The indicator with revolution counter installed in the throttle station (fig. 12-7) is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a meter, 1F synchro receiver, revolution

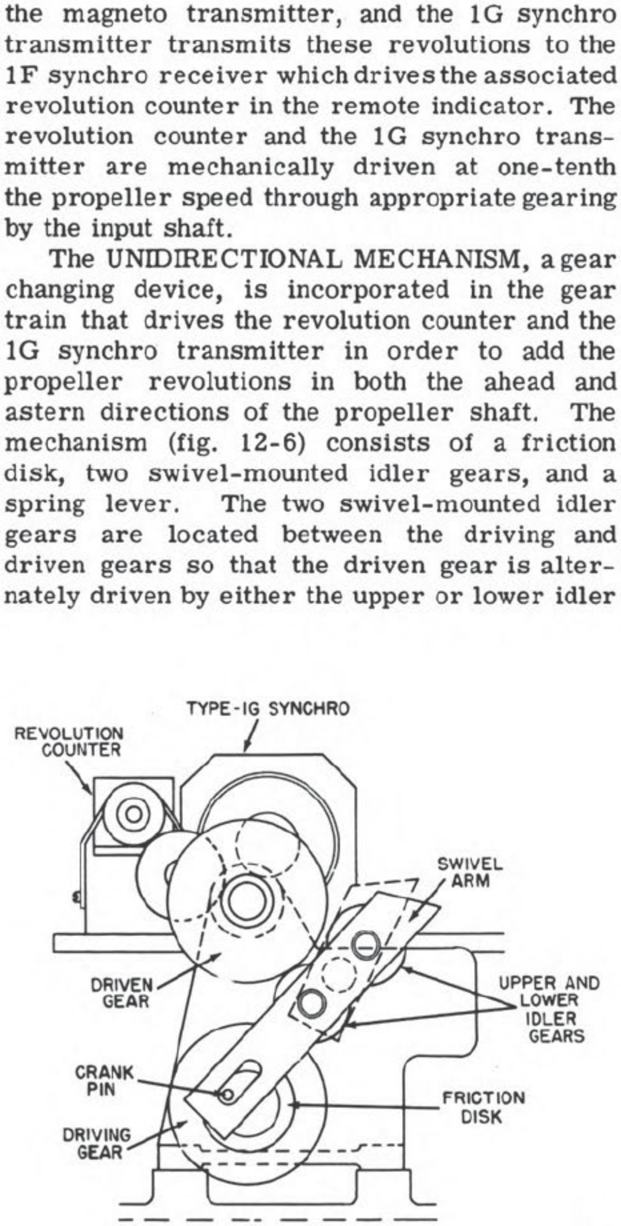

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Figure 12-6.—Schematic diagram of unidirectional mechanism.

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Figure 12-7.—Voltmeter-type indicator with revolution counter.

counter, and backing signal lamp. A revolving pointer indicates on the dial the rpm of the associated propeller shaft.

The METER is essentially a d-c voltmeter calibrated in terms of propeller rpm so that an impressed terminal voltage of approximately 3600 millivolts will cause a full-scale deflection of the pointer. The meter is energized by the generated output voltage of the d-c magneto located in the shaft transmitter unit.

The REVOLUTION COUNTER is driven through gears by the 1F synchro receiver (fig. 12-5) to indicate the total rpm of the propeller shaft. The 1F synchro receiver is driven electrically by the 1G synchro transmitter in the associated shaft magneto transmitter.

THE BACKING SIGNAL INDICATOR consists of a double lamp assembly provided with a 115/6-volt transformer and red target window. When the propeller shaft rotates in the astern direction, the unidirectional mechanism in the shaft transmitter actuates the SPDT switch to energize the lamps and illuminate the red target window.

Indicator

The indicator installed in the pilot house (fig. 12-5) is used to indicate the rpm of the propeller shaft. It is similar in appearance and construction but smaller than the previously described unit installed in the throttle station (fig. 12-7). The unit is provided with dial illumination and a dimmer rheostat but does not include a revolution counter.

WIND DIRECTION AND SPEED INDICATOR SYSTEM

The wind direction and speed indicator system, circuits HD and HE, is used to indicate instantaneous and continuously the (1) wind direction in degrees relative to the ship's heading, and (2) wind speed in knots relative to the ship. A gyrocompass repeater is provided as an accessory to the system in order to determine the TRUE wind direction.

The type-B wind direction and speed indicator system may be modified by adding a synchro signal converter and a synchro isolation amplifier. The converter and amplifier convert the 60-cycle signal to a 400-cycle signal for those ships using special weapons systems.

TYPE-B EQUIPMENT

The schematic diagram of a representative type-B wind direction and speed indicator system installed in a large ship is illustrated in figure 12-8. The system consists of a (1) wind direction and speed detector, (2) wind direction and speed transmitter, and (3) wind direction and speed indicator. Two wind direction and speed detectors are mounted on the foremast, one on the port side and one on the starboard side. The wind direction and speed transmitter is installed in the I.C. room. The wind direction and speed indicators are installed in various navigational spaces as required by the type of ship.

Detector

The wind direction and speed detector (fig. 12-9) consists of a thin-gage monel metal housing formed into a streamlined wind vane with a relatively large tail surface mounted on a vertical support assembly. The rotor assembly. attached to the head of the vane is held directly into the wind by the vane assembly and converts the wind speed into rotary motion. The speed of rotation of the rotor assembly is proportional to the velocity of the wind striking the rotor blades.

The DIRECTION SYNCHRO TRANSMITTER. mounted in the vertical support assembly, is directly coupled to the vane so that when the wind positions the vane, the synchro transmitter is displaced the same angular amount. The angular positions are transmitted electrically to the 1HCT synchro control transformer in the wind direction subassembly of the transmitter unit (fig. 12-8). Because wind directions are indicated in relative bearings, the direction synchro transmitter is set to electrical zero when the rotor assembly of the detector unit points to the bow of the ship.

The SPEED SYNCHRO TRANSMITTER. mounted in the head of the vane, is coupled through gears to the rotor assembly so that the synchro rotates 1 revolution for each 12.5 revolutions of the propeller. The reduced rotary motions are transmitted electrically to the 1F synchro receiver in the wind speed subassembly of the transmitter unit (fig. 12-8). Electrical connections to the speed synchro are provided through collector rings and brushes.

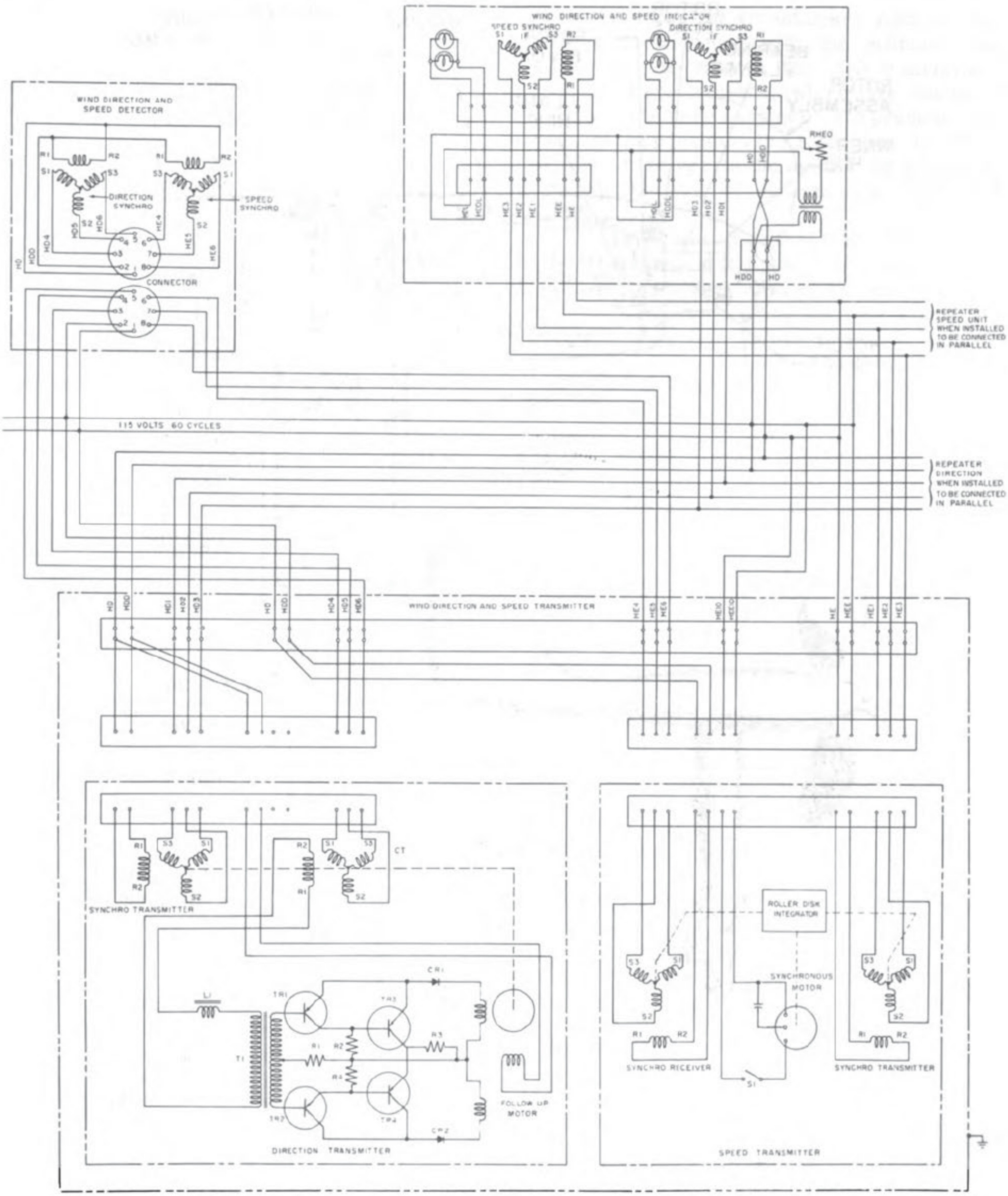

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Figure 12-8.—Schematic diagram of type-B wind direction and speed indicator system.

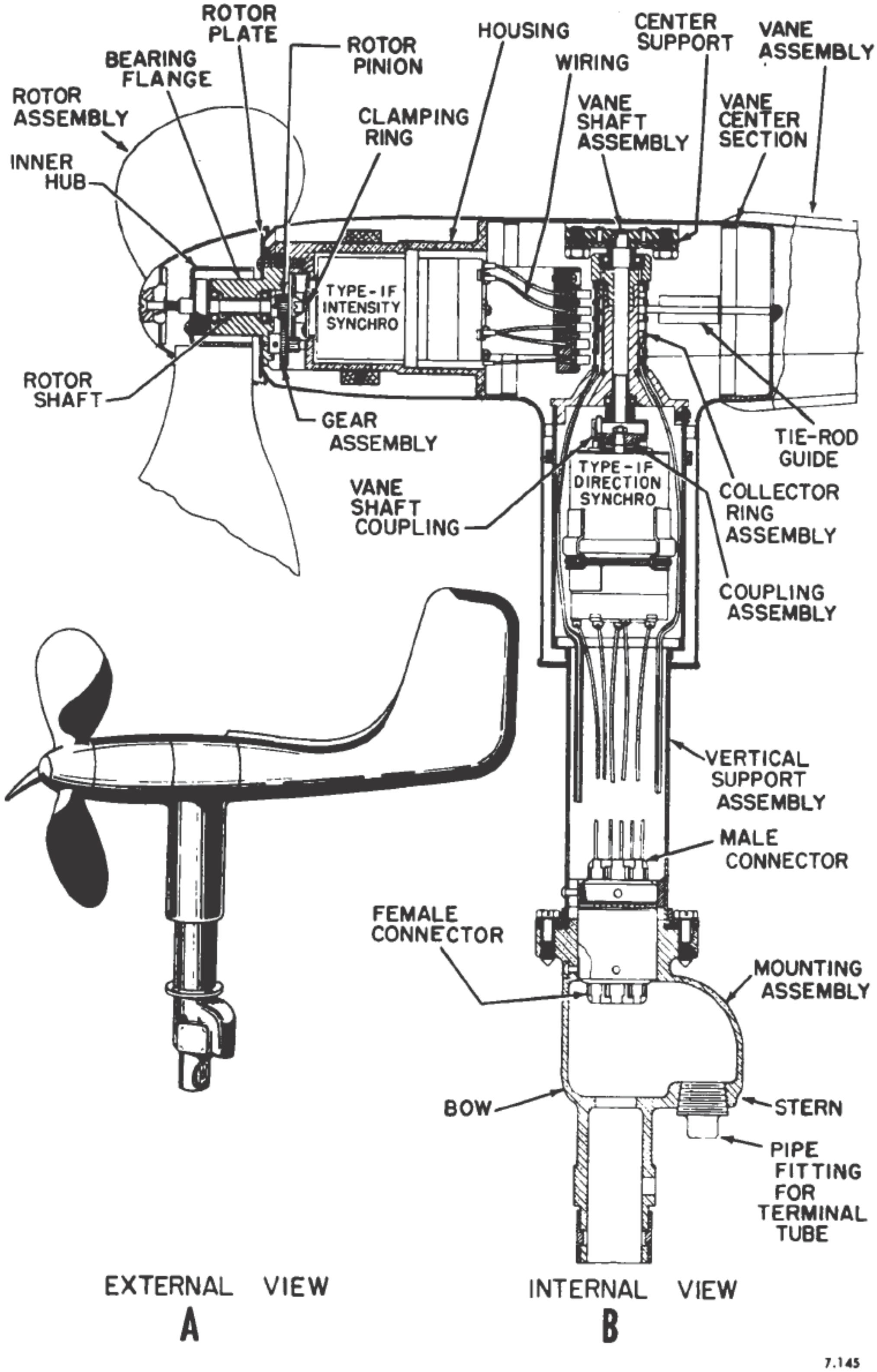

Figure 12-9.—Wind direction and speed detector.

The mounting assembly and the vertical support assembly are provided with flanges for bolting the two sections together. The detector is held in alignment by a mounting bolt that serves as a dowel. The incoming cable is brought into the unit through a watertight terminal tube in the bottom of the mounting assembly and is connected to a female connector in the top of this assembly. The leads for the synchros are connected to a male connector in the bottom of the vertical support assembly. Thus, the detector mechanism can be removed without disconnecting the incoming leads or disturbing the alignment.

Transmitter

The wind direction and speed transmitter (fig. 12-8) consists of a wind direction subassembly and a wind speed subassembly mounted on individual baseplates to form a complete unit enclosed in a metal case designed for bulkhead mounting.

The WIND DIRECTION SUBASSEMBLY (fig. 12-10) is essentially a servo unit comprising a 1HCT synchro control transformer, followup control, and 5HG synchro transmitter. The synchro control transformer receives the angular displacements from the direction synchro transmitter in the detector. These angular displacements are amplified and fed to the followup motor which drives the 5HG transmitter and control transformer through gears into correspondence with the synchro transmitter in the vane. The 5HG transmits the angular displacements, which are damped by means of the gear assembly, at a predetermined rate of approximately 1.25 rpm to the 1F synchro receiver in the associated wind direction subassembly of the remotely located indicator.

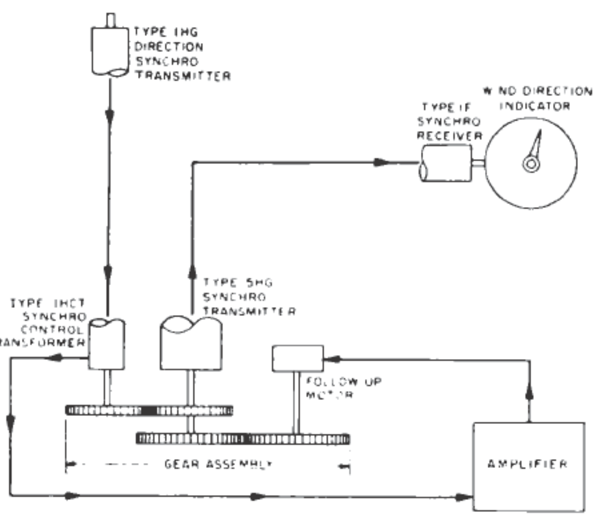

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Figure 12-10.—Schematic diagram of wind direction subassembly.

When the vane direction transmitter and the synchro control transformer rotors are in correspondence, the output of the control transformer is zero. When the vane changes its position, the two rotors are no longer in correspondence and a voltage is induced in the rotor of the control transformer because the stator field links the rotor winding. The output voltage of the control transformer is either in phase or 180 degrees out-of-phase with the source (reference) voltage, depending on the direction in which the vane has turned. Thus, the phase of the control transformer reverses with respect to the transmitter reference voltage as the direction of displacement reverses. The magnitude of the control transformer output voltage represents the amount by which the shafts of the control transformer and the vane transmitter are out of correspondence. The direction in which the transmitter shaft is turned represents the phase of the control transformer output voltage which determines the direction of rotation of the followup motor.

The signal from the control transformer (fig. 12-8) is fed to the input transformer T1 of the amplifier. The series inductor L1 in the primary of T1 compensates for the phase shift inherent in the control transformer so that the signal applied to the primary of T1 is exactly in phase or 180 degrees out-of-phase with the reference voltage. Transformer T1 also isolates any direct current in the circuit of the secondary winding from the synchro control transformer. The secondary of T1 is connected to the amplifier, consisting of the paralleled transistors TR1-TR2 and TR3-TR4 connected for push-pull operation. Transistors TR1 and TR2 are connected as emitter followers which offer a high impedance to T1, and thus prevent overloading of the synchro control transformer. The output of TR1-TR3 and TR2-TR4 is connected to the control windings CCW and CW of the split-phase followup motor through rectifiers CR1 and CR2, respectively. When the vane

changes its position, the upper section (TR1-TR3), or the lower section (TR2-TR4), conducts and applies the amplifier output to the CCW or CW winding to drive the followup motor in the direction corresponding to that in which the vane transmitter rotor is displaced. The followup motor positions the 5HG transmitter and drives the rotor of the control transformer into correspondence with the vane transmitter rotor to null the signal and stop the motor.

The rectifiers CR1 and CR2 between the transistors and control windings of the followup motor restrict the direction of current flow in the transistors and control windings. The resistors R2 and R3 connected in the base circuits of transistors TR3 and TR4 serve to provide low resistance shunt paths for the collector leakage currents which may reach excessive values of high ambient temperatures. Resistor R1, connected in the common emitter return circuit, provides degenerative bias to further stabilize the operating points of transistors TR3 and TR4. Resistor R1 also serves to drive the nonconducting transistor to cutoff when an error signal is present at the other transistor base, thereby improving the performance at all ambient temperatures.

The WIND SPEED SUBASEMBLY (fig. 12-11) is essentially a roller disk integrator comprising a 1F synchro receiver, a roller gear assembly with worm and circular rack, constant speed motor, and 5HG synchro transmitter. The 1F synchro receives the rotary motions from the vane speed transmitter, the roller gear assembly converts the rate of these rotary motions into proportional angular displacements, and the 5HG synchro transmits these displacements to the 1F synchro receiver in the associated wind speed subassembly of the remotely located indicator.

The 1F synchro receiver, which rotates at the same speed as the 1HG speed transmitter in the detector, transmits the rotary motion through reduction gears to the worm of the roller gear assembly. This gear reduction terminates with a spiral gear that engages the worm of the roller gear assembly. The action of the sprial gear against the worm of roller gear assembly is that of a pinion on a rack which drives the drive roller away from the center of the two driving disks in a linear motion. However, the drive roller with its integral worm and circular rack are rotated by the two driving disks, which turn in opposite directions, by a constant speed (synchronous) motor through reduction gears and the two disk drive gears.

The speed of the circular motion of the drive roller depends on the position of the roller with respect to the center of the driving disks. The speed of the drive roller increases as the roller approaches the edge of the disk. Hence, the drive roller receives circular motion and linear motion simultaneously. Although the driving action of the spiral gear against the worm tends to drive the roller away from the center of the two disks, the motion resulting from the revolving of the worm engaging the spiral gear is toward the center of the disks. When the circular motion and the linear motion balance each other, the drive roller assures a position of displacement from the center of the disks that is proportional to the rotor speed of the 1HG speed transmitter in the detector.

The drive roller is attached to the roller gear assembly shaft and positions this shaft laterally. The circular rack of the roller gear assembly engages a pinion on the shaft of the 5HG synchro transmitter, thereby transforming linear motion into angular motion. The angular motion is transmitted to the wind speed subassembly in the remotely located indicator. The 5HG synchro transmitter is set to electrical zero when the wind speed is zero.

A low-limit switch, S1 (fig. 12-8) is provided to open the circuit to the synchronous motor when the drive roller is at the center of the driving disks at zero wind speed. As the roller nears the center of the disks, the end of the worm gear forces a bell crank (not shown) to open switch, S1, and deenergize the circuit to the synchronous motor. This switch saves needless wear on the disks and roller when there is no wind speed to be indicated.

Indicator

The wind direction and speed indicator (fig. 12-12) is a dual unit consisting of a wind direction subassembly and a wind speed subassembly. The two subassemblies are identical except for the dials. Each consists of a 1F synchro receiver indicating on a fixed dial by means of a revolving pointer directly attached to its shaft. The subassemblies are mounted on individual baseplates and enclosed in a metal housing to form a complete wind direction and speed indicator unit.

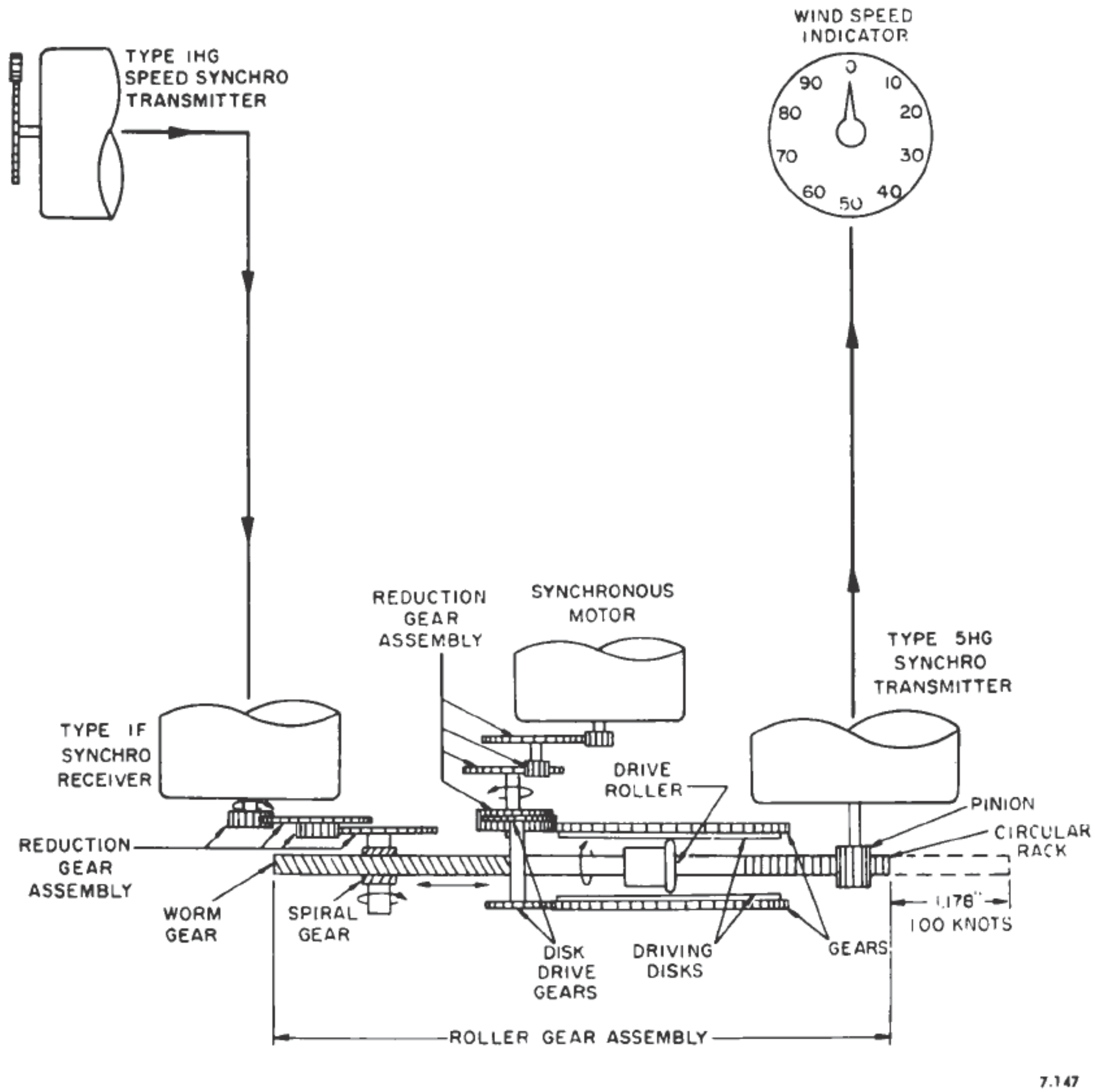

Figure 12-11.—Schematic diagram of wind speed subassembly.

The 1F direction synchro receives the angular displacements from the 5HG synchro in the direction subassembly of the transmitter unit and indicates these displacements on the direction dial. The direction dial is graduated in 10° intervals from 0° to 360°.

The 1F speed synchro receives the angular displacements from the 5HG synchro in the speed subassembly of the transmitter unit and indicates these displacements on the speed dial. The speed dial is graduated in 5-knot intervals from 0° to 100 knots through 360°.

The dials and pointers are red illuminated. Dial illumination for each subassembly is provided by two lamps in parallel supplied from a 115/6-volt transformer inside the housing. A knob on the side of the case controls a rheostat for varying the intensity of illumination.

SALINITY INDICATOR SYSTEM

The salinity indicator system, circuit SB, is used to indicate the amount of salinity in water systems aboard ship. The system is a necessity aboard ship because all fresh water, particularly

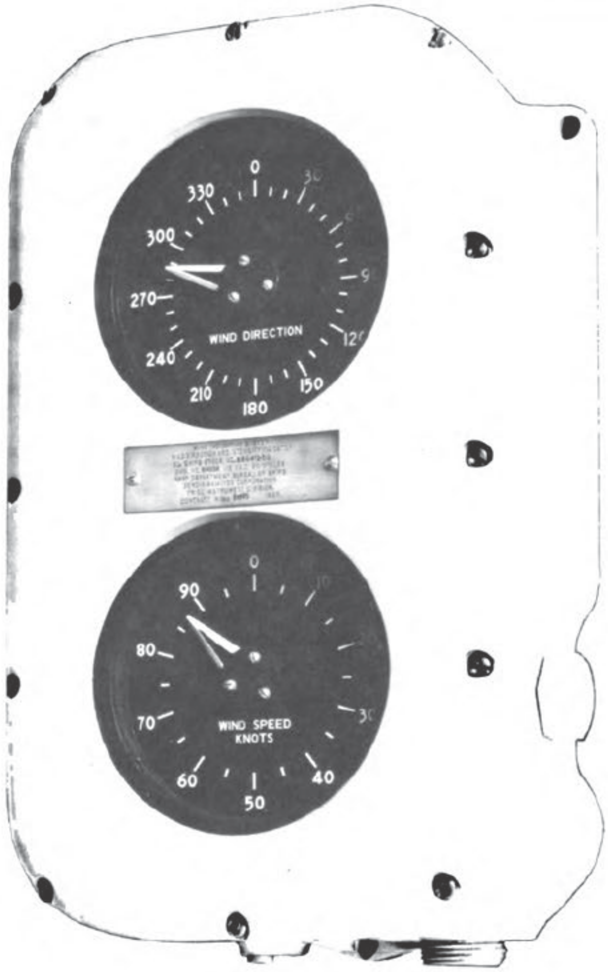

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Figure 12-12.—Wind direction and speed indicator.

when underway, is made from sea water. Excessive salinity in the boiler feed water causes pitting of the tubes and rapid deterioration due to electrolysis. Salinity indicators are usually provided in the enginerooms and the firerooms for checking the condensate from the main and auxiliary condensers. They are also provided for the evaporator plants to indicate the degree of purity of the fresh water and condensate at various selected points in the distilling system.

The operation of the salinity indicator system is based on the principle that an increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and conversely, that a decrease in the impurities increases the electrical resistance of the water. If two electrodes are immersed in the water being tested and a constant alternating voltage is applied across the electrodes, a constant alternating current will flow, provided the impurity content and the temperature of the water remain unchanged.

The amount of current flow is indicated on a meter, the scale of which is graduated in EQUIVALENT PARTS PER MILLION. If the saline content of the water increases because salt water leaks into the system or because the operation of the distilling plant becomes faulty, the conductivity between the electrodes increases and the meter reading increases an amount that is proportional to the increase in salinity.

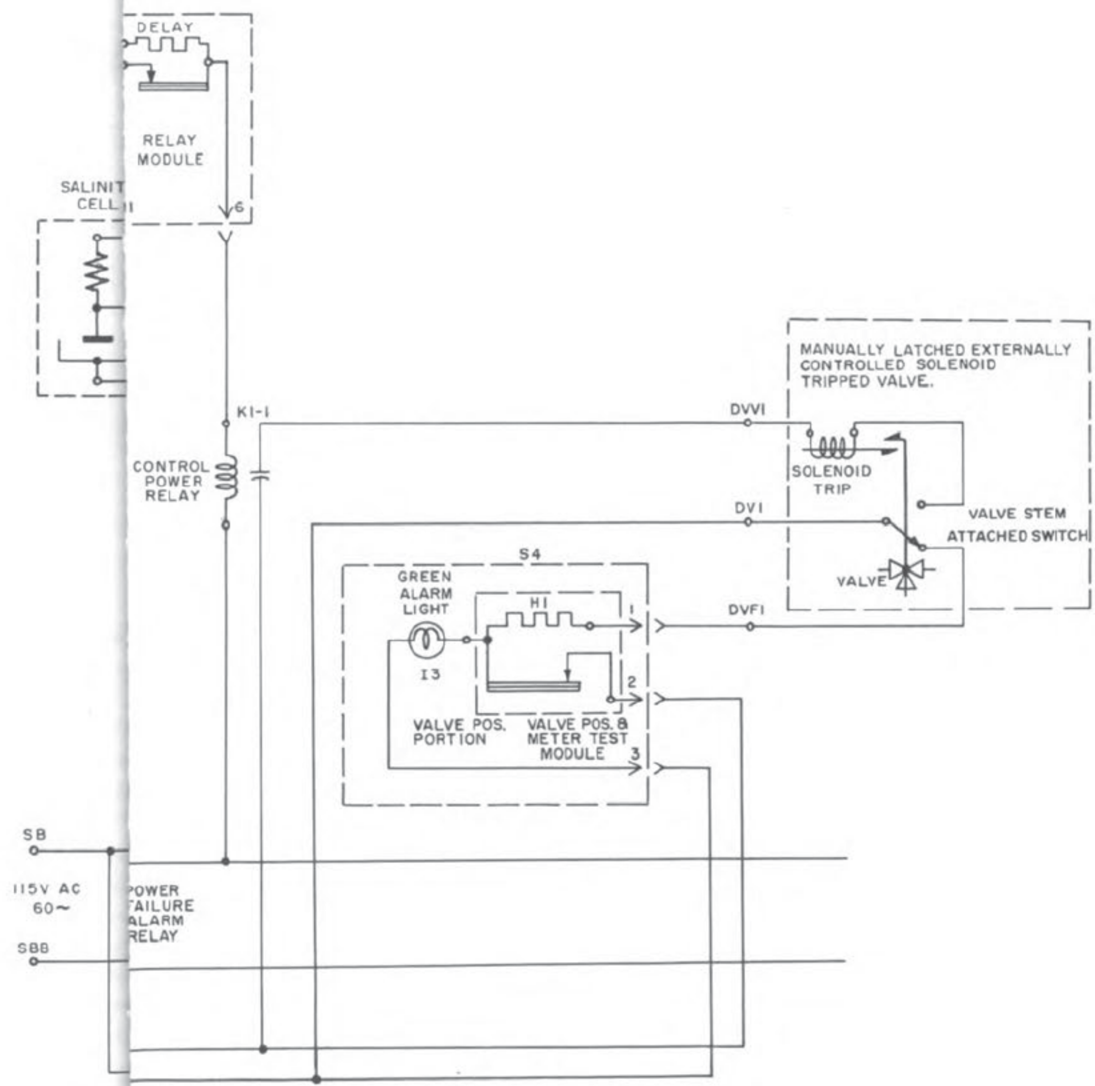
A complete salinity indicator system consists of one or more salinity cells and an indicator panel. The salinity cells measure the conductivity and thermal conditions of the water and transmit the measurements to the salinity indicator panel. The salinity indicating meter provided on the panel has a pointer which moves over a logarithmic scale calibrated in parts per million (PPM) of chloride. Each salinity cell including the associated circuits, indicators, and switches constitute one salinity channel. A salinity indicator system is illustrated by the schematic diagram in figure 12-13. For simplicity, only one salinity channel is shown.

SALINITY CELL AND VALVE ASSEMBLY

The salinity cell and valve assembly is illustrated in figure 12-14.

The VALVE is a standard 1 1/4-inch cast-bronze wedge-seated valve with an externally threaded stem (fig. 12-14, A). It is rated at 125 psi for steam pressure and is hydrostatically tested to 200 psi. The valve is fitted into the water system piping by means of a standard approved tee and provides a means of shutting off the water when withdrawing the salinity cell for cleaning and inspection.

The SALINITY CELL is a self-contained unit consisting of a nipple, packing nut, cell tube, and electrode assembly (fig. 12-14, B). The cell tube provides a means of extending the electrode assembly through the valve and is connected to the tee through the nipple and packing nut to form a watertight seal. The packing nut has a set screw that screws into a groove in the cell


DELAY
RELAY MODULE
6
SALINIT
CELL
11
MANUALLY LATCHED EXTERNALLY CONTROLLED SOLENOID TRIPPED VALVE.
K1-1
DVV1
CONTROL POWER RELAY
SOLENOID TRIP
DV1
VALVE STEM ATTACHED SWITCH
S4
GREEN ALARM LIGHT
VALVE
H1
1
DVF1
I3
2
VALVE POS. PORTION
VALVE POS. & METER TEST MODULE
3
SB
115V AC 60~
POWER FAILURE ALARM RELAY
SBB

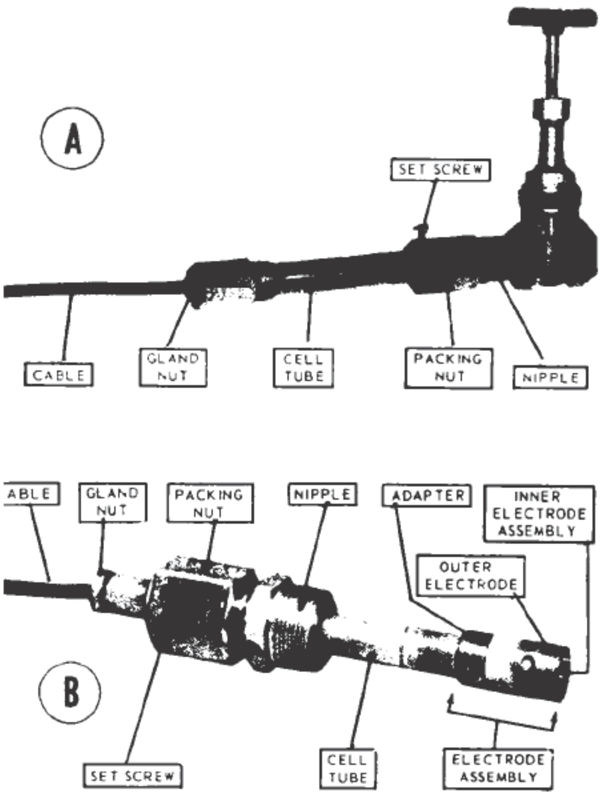


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Figure 12-14.—Salinity cell and valve assembly.

ube to prevent axial displacement of the tube by he hydrostatic pressure. A steel ring stop on he cell tube, between the packing nut and nipple, ocates the cell properly in the piping.

A 6-foot, 3-conductor cable connects the cell o the salinity indicating panel through the hip's 115-volt 60-cycle power. The cable is ecured to the cell by means of a gland nut. The hree conductors in the cable are color coded reen, white, and black. The green conductor onnects the outer electrode of the cell which is rounded through the piping to the ship's hull, o the panel terminals labeled SSB 10, 20, 30, and o forth (fig. 12-13). The white conductor conects the inner electrode to panel terminals abeled SB 10, 20, 30, and so forth. The black onductor connects the automatic temperature ompensator to panel terminals labeled SB 11, 21, 31, and so forth.

The electrode assembly comprises the inner electrode, adapter, automatic temperature compensator, and the outer electrode. The INNER ELECTRODE is a hollow platinum-coated brass cylinder closed at the forward end. It is held in the adapter by means of a spring-loaded nut on the end of the inner electrode holder. A solder lug under this nut connects the white conductor of the incoming cable.

The OUTER ELECTRODE is a hollow brass cylinder the inside of which is coated with a thin layer of platinum. This electrode screws onto the adapter which in turn screws onto the cell tube. It is pierced with holes to vent the gases trapped in the space between the electrodes and to allow for free circulation of the water. The connection for the outer electrode is made by soldering the green conductor of the incoming cable into the hole provided in the cell tube.

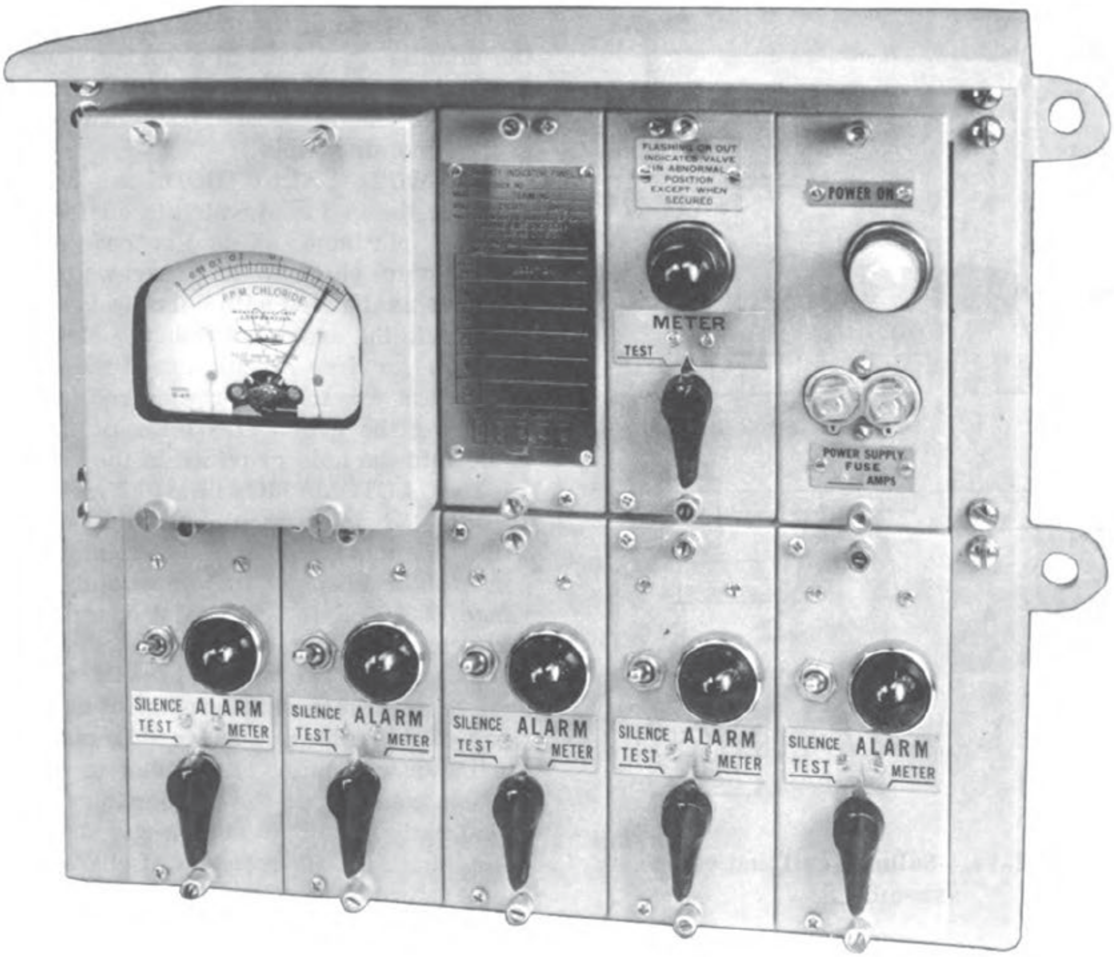
The AUTOMATIC TEMPERATURE COMPENSATOR is a small circular disk located within the inner electrode to automatically compensate for changes in temperature through a range of 40° F to 250° F. It consists of a material having a negative temperature coefficient of resistance. The material has the same resistance temperature characteristics as dilute solutions of sea water. The conductance between the inner and outer electrodes is balanced by the conductance of the temperature in an electrical ratio circuit in such a way that the alarm point signal is independent of changes in water temperature. One side of the compensator disk is soldered to the closed end of the inner electrode and the other side has a lead brought out through the inner electrode holder to the black conductor of the incoming cable.

SALINITY INDICATOR PANEL

The salinity indicator panel (fig. 12-15) is designed to function in a system having five salinity cells, external alarm bells, and two solenoid trip valves. The panel contains a power unit, meter unit, five salinity cells, valve position and meter test unit, and a relay unit. The units are of the plug-in type to facilitate removal for inspection and repairs.

Power Unit

The ship's 115-volt 60-cycle power is applied to the salinity indicator panel through the power unit (fig. 12-15). The power unit is not a plug-in type, but is wired directly onto the panel. It is provided with a white power-on indicator lamp,



7.15

Figure 12-15.—Salinity indicator panel.

two fuse holders, and two blown-fuse indicators. The two fuses protect only the salinity cell and the alarm circuit wiring. The power circuits to the solenoid-operated control valves are not fused.

Meter Unit

The meter unit (fig. 12-15) measures the specific electrical conductivity of the water. The conductivity values are then converted by meter scale calibration into equivalent concentrations of sea water. The meter is connected to the cell circuits by individual switches on each salinity cell. The specific electrical conductivity is measured by means of a bridge circuit which employs a special power-factor type meter (fig. 12-13). The meter measures the ratio of currents in the two separate arms of the bridge. One arm of the bridge is the dilute solution of sea water to be measured. The other arm of the bridge is an automatic temperature compensating resistor which has the same resistance-temperature characteristics as dilute solutions of sea water.

The power-factor-type meter employs a fixed coil and a movable coil. The movable coil consists of two windings, A and B, at right angles to each other. It is free to rotate within the fixed coil. The movable coil is energized from the secondary of power transformer, T1. Hence, the currents in windings A and B are in phase with each other and the circuits are resistive because of the series limiting

resistor, R6. The fixed coil is energized from the ship's 115-volt 60-cycle power supply in series with the voltage dropping resistor, R12. The movable coil turns until its resultant field lines up with the field of the fixed coil. Therefore, the meter indication is directly dependent on the resultant field of the two movable windings, which in turn is dependent on the ratio of the currents in the two windings. The meter indication is independent of minor voltage and frequency changes of the power supply because there is no iron on the meter magnetic circuits and because the coil circuits are essentially resistive.

It is apparent that the currents in the two windings of the movable coil are proportional to the two loads in the bridge circuit. As previously stated, the load in one leg of the bridge (movable winding, A) is the automatic temperature compensator, C, in the other leg (movable winding, B) is the resistance of the water being measured by the electrodes, E. The meter reading which is determined by the ratio of the currents in the crossed windings, is therefore determined by the ratio of the cell resistance and the compensator resistance. At any given salinity and temperature there is only one possible meter reading. If the temperature is either raised or lowered from this point, the meter reading will remain unchanged because of the action of the compensator even though the water resistance may change appreciably. The temperature compensation occurs because any thermal change of the water being measured by the cell is immediately transferred to the automatic temperature compensator. The resistance of the compensator is inversely proportional to its temperature so that the thermal change transmitted to the compensator causes its resistance to change accordingly.

The resistance-temperature characteristics of the compensator are the same as those of dilute solutions of sea water. Therefore, the thermal change in the compensator, which is exactly the same as the thermal change of the sea water, causes sufficient resistive change in the compensator to compensate for the resistive change occurring in the cell. Although the absolute values of current in the windings have changed, their ratio has not changed and consequently the meter reading is unchanged. Because the temperature compensation is equally effective at all salinities, the only change that can vary the meter reading is a change in the current ratio caused by a change in salinity.

Salinity Cell Unit

A salinity cell plug-in unit (fig. 12-15) is provided for each salinity cell to continuously monitor the purity of the water of the cell. The unit consists of an alarm circuit which includes a dual potentiometer R1, signal transformer T2, thyratron tube V1, flasher H2, red indicator lamp I2, and silence switch S2. A 3-position selector switch S1 is also provided on the unit (fig. 12-13). The alarm point value is predetermined and set. A high salinity condition is indicated initially by flashing of the red indicator light and sounding of the external audible alarms.

The ALARM CIRCUIT can be traced from the salinity cell electrodes and compensator through the dual potentiometer R1 to the primary of the signal transformer T2, the secondary of which is connected to the control grid and cathode of the thyratron V1. The plate and cathode of V1 are connected across the 115-volt 60-cycle power supply in series with the flasher H2, and the red indicator lamp I2.

There are two circuits from the secondary of power transformer T1 through the salinity cell, dual potentiometer R1, and primary of signal transformer T2. One circuit is through the electrodes, lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The other circuit is through the compensator C, resistor R5, the upper arm of R1, the primary of T2, the lower arm of R1, and resistor R6. The conductance values of the salinity cell electrodes and compensator which are applied to the secondary of T1 and to the two arms of potentiometer, R1 determine the grid to cathode voltage of V1. The current flow through the two arms is in opposite directions or 180 degrees out-of-phase and the resultant voltage is impressed across the primary of T2.

When the salinity condition of the cell is lower than the alarm setting, the currents through the bridge circuit comprising the two arms of potentiometer R1 are equal and opposite, no voltage is impressed on the primary of T2, and V1 does not conduct. The silence switch S2 is in the NORMAL (up) position and the red indicator light is extinguished indicating that the salinity is of a safe value.

On the other hand, when the salinity condition of the cell is higher than the alarm setting, the resistance across the two electrodes is decreased and more current flows through the lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The resultant voltage is impressed across the grid and cathode of V1 through transformer T2. This action causes V1 to conduct during the half cycles when the grid and plate voltages of V1 are positive. The circuit is completed from one side of the line SB through the cathode and plate of V1, silence switch S2, rectifier CR4, flasher H2, rectifier CR3, red indicator lamp I2, to the other side of the line SBB.

The SILENCING SWITCH S2, when placed in the SILENT (down) position, clears the external alarm circuit for other incoming alarms and causes the red indicator lamp to light steadily. When the high salinity condition is corrected, the red indicator light again flashes to remind the operator to place the switch S2 in the NORMAL (up) position to extinguish the red indicator lamp and clear the unit for future alarm signals.

The selector switch S1 (fig. 12-13) is a 3-position, spring-loaded switch having a NORMAL (center) position, TEST position, and METER position. The selector switch S1, when placed in the TEST position, disconnects resistor R5B, in the salinity cell circuit resulting in an unbalanced condition which causes the cell to behave as though a high salinity condition exists. This action energizes the alarm circuit causing the red indicator light to flash and the alarm relay to sound the external alarm. The selector switch, S1, when placed in the METER position, connects the meter unit in the circuit of the associated salinity cell and a salinity reading is indicated on the meter.

Relay Unit

The relay unit (fig. 12-13) consists of an alarm relay K2 and two 2-second delay flashers. For simplicity, only one flasher is shown. The flasher is used to delay the tripping time of the solenoid-operated valves. Normally, the current through the delay flasher contact circuit is not sufficient to open the flasher contacts. However, if terminal 5 of the relay unit is energized from an associated salinity cell, the flasher contact will open and close intermittently. This action opens the valve control circuit causing the valve to actuate.

The rectifier CR2 allows a current to flow through the operating coil of alarm relay K2, from the plate of V1, through switch S2, in the NORMAL (up) position and back to the other side of the line SBB. Rectifier CR5, across the coil of K2, maintains the current flow through the coil during the nonconducting half cycles of V1. The contacts of relay K2 close to energize the external alarm circuit.

The silencing switch S2, when placed in the SILENT (down) position, opens the circuit to the audible alarm and connects the flasher H2, in the salinity cell unit, directly to the cathode of V1 through rectifier CR4, to ensure that H2 operates at all times. As long as the salinity is higher than the alarm setting, CR2 allows a current to flow directly through the red indicator lamp I2, which is lighted steadily. During this condition, CR3 prevents a large current flow through the heater of flasher, H2. When the salinity decreases to a value at which V1 ceases to conduct, the flasher heater voltage causes the red indicator light to flash as a reminder for the operator to place the silencing switch S2 in the NORMAL (up) position.

Normally, the current flows through the relay unit from the line terminal, SBB, the bimetallic arm of the delay flasher, the coil of the power control relay K1-1, to the line terminal SB. This current maintains power relay K1-1, operated so that its contacts energize the coils of the solenoid-operated valves. For simplicity, only one solenoid-operated valve is shown.

Valve Position and Meter Test Unit

The valve position and meter test unit (fig. 12-15) is provided with a green valve position indicator lamp and a meter test switch. The dual purpose of the unit is to indicate when the control valve is in the NORMAL or ABNORMAL position and to provide a means of testing the meter unit.

When the solenoid trip valve is in the NORMAL position the green indicator lamp is lighted steadily; when the control valve disk is in the ABNORMAL position the green inicator light flashes; and when the control valve is reset manually the green indicator lamp is again lighted steadily.

The meter test switch, when placed in the TEST position, connects the meter unit in a circuit simulating a known salinity condition (1.7 PPM) to check the calibration of the meter.

The valve position portion of the unit (fig. 12-13) consists of the green indicator lamp I3 and the flasher H1, interconnected with the solenoid-operated valve. During normal operating conditions the solenoid is energized from line terminal SSB through the contacts of the power control relay K1-1, terminal 1 of the SPDT switch, S4 (on the control valve), to line terminal SB. The green indicator lamp I3 is lighted steadily during this condition from line terminal SB, the contact arm of flasher H1, to line terminal SBB.

When an abnormal condition occurs, the power control relay K1-1 is deenergized and its contact opens the circuit to the solenoid coil which actuates switch S4. This action connects the heater and contact arm of flasher H1 from line terminal SB, through terminal 2 of switch S4, to line terminal SBB causing the green indicator light to flash.

The meter test portion of the unit (fig. 12-13) consists of the meter test switch S3, resistor R10, and potentiometer R11. Normally, the meter unit is not connected to any salinity cell. The meter test switch S3 is a 2-position, spring-loaded rotary switch having a NORMAL (center) position and a TEST position. The rotary switch S3 when placed in the TEST position, connects the movable windings A and B of the power-factor-type meter in a circuit comprising resistor R10 and potentiometer R11, the resistances of which duplicates the resistances of the electrodes and compensator. There are two circuits through the movable windings. One circuit is from line terminal SB, the right arm of potentiometer R11, terminal 4 of switch S3, resistor R10 to line terminal SBB. The other circuit is from line terminal SB, the left arm of potentiometer R11, terminal 5 of switch S3, movable winding B, terminal 6 of switch S3, resistor R10, to line terminal SBB.

UNDERWATER LOG SYSTEM (ELECTROMAGNETIC TYPE)

The underwater log systems, circuit Y, is used to measure the speed of the ship in knots and the distance traveled through the water in nautical miles. It transmits this information to the various fire control and navigational equipments as required by the particular types of ships.

The general types of underwater log equipments installed in naval vessels are the (1) pitot-static or hydraulic type, (2) propeller or electromechanical type, and (3) electromagnetic type. The electromagnetic-type equipment described in this training course is rapidly replacing the hydraulic and electromechanical-type equipments.

The electromagnetic-type underwater log system is illustrated by the block diagram in figure 12-16. The equipment consists of a (1) rodmeter, (2) sea valve, and (3) indicator-transmitter. The rodmeter and sea valve are described in the training course, *I. C. Electrician 3*, NavPers 10555-A.

INDICATOR-TRANSMITTER

The indicator-transmitter (fig. 12-17) contains all the electrical and electromechanical components of the log equipment except the components contained in the rodmeter. The unit is electrically connected to the rodmeter by two 2-conductor cables which terminate in connectors that fit receptacles in the lower part of the case. The principal components of the indicator-transmitter are the (1) speed servo, (2) integrator, and (3) distance servo.

Speed Servo

The speed servo (fig. 12-18) functions to translate the signal voltage generated by rodmeter into a mechanical angular output which drives the speed dial, speed synchro transmitter, and the input to the integrator.

The input transformer T2 functions as an error detector. It receives the speed voltage generated by the rodmeter and a response signal which is an indication of the positions of the load. When an error exists between the position of the load and the position called for by the speed signal, an error signal is generated, by the input transformer. The error signal is fed to the amplifier which produces the power necessary to drive the speed servomotor in accordance with the error signal. When the load is correctly positioned in accordance with the speed signal, the error voltage is zero. The response signal is initially produced by the voltage drop across

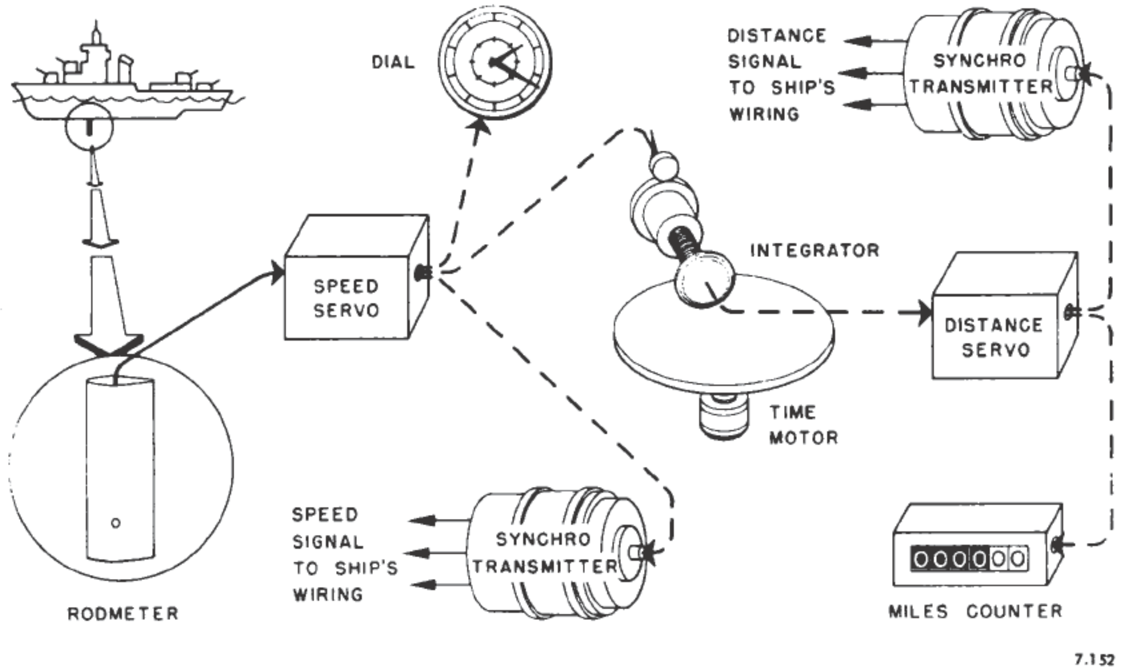


Figure 12-16.—Block diagram of electromagnetic-type underwater log system.

resistor R9 in the rodmeter coil supply. The magnitude of the response signal is adjusted by the response potentiometer R10 which is driven through gears by the speed servomotor B1.

AMPLIFIER.—The amplifier (fig. 12-19) consists of the input transformer, a 4-stage vacuum-tube voltage amplifier with its power supply, and a 2-stage self-saturating magnetic power amplifier that drives the speed servomotor B1. Each stage of the 4-stage voltage amplifier is a separate interchangeable plug-in unit equipped with twin triode tube.

The input transformer, as previously stated, functions as an error detector. The primary of T2 is excited by the response voltage from the response potentiometer R10. The two secondary windings are connected in series with the pickup buttons on the rodmeter. The response voltage is connected in phase opposition to the speed voltage. Therefore, the response voltage and the speed voltage add algebraically within the transformer. The algebraic sum of these two voltages is an error signal voltage which is fed to the amplifier. When the magnitude of feedback voltage is equal to the magnitude of the speed voltage, the resulting error is zero.

If the ship's speed increases, the algebraic sum of the voltages will produce an error signal in phase with the speed signal and will drive the speed servo system in the increasing direction. Conversely, if the ship's speed decreases, the resulting error signal will be 180 degrees out-of-phase with the speed signal and will drive the servo system in the decreasing direction.

The error signal from transformer T2 is coupled to the grids of the first stage of the voltage amplifier through capacitors C2 and C1 of the first plug-in unit AR1. Capacitor coupling is used to block any d-c voltage that might be picked up by the rodmeter from stray d-c fields in the water.

The voltage amplifier consists of four conventional R-C coupled push-pull stages of voltage amplification. Each stage functions in push-pull to amplify unbalanced signals (that tend to produce opposite polarities on each grid of the twin triodes) and to suppress balanced signals (that tend to produce the same polarity on both grids). For example, consider a signal which tends to produce the same polarity on both grids. A positive signal on both grids at a given instant will tend to increase the plate current and the current through R3 in V1A. The increased

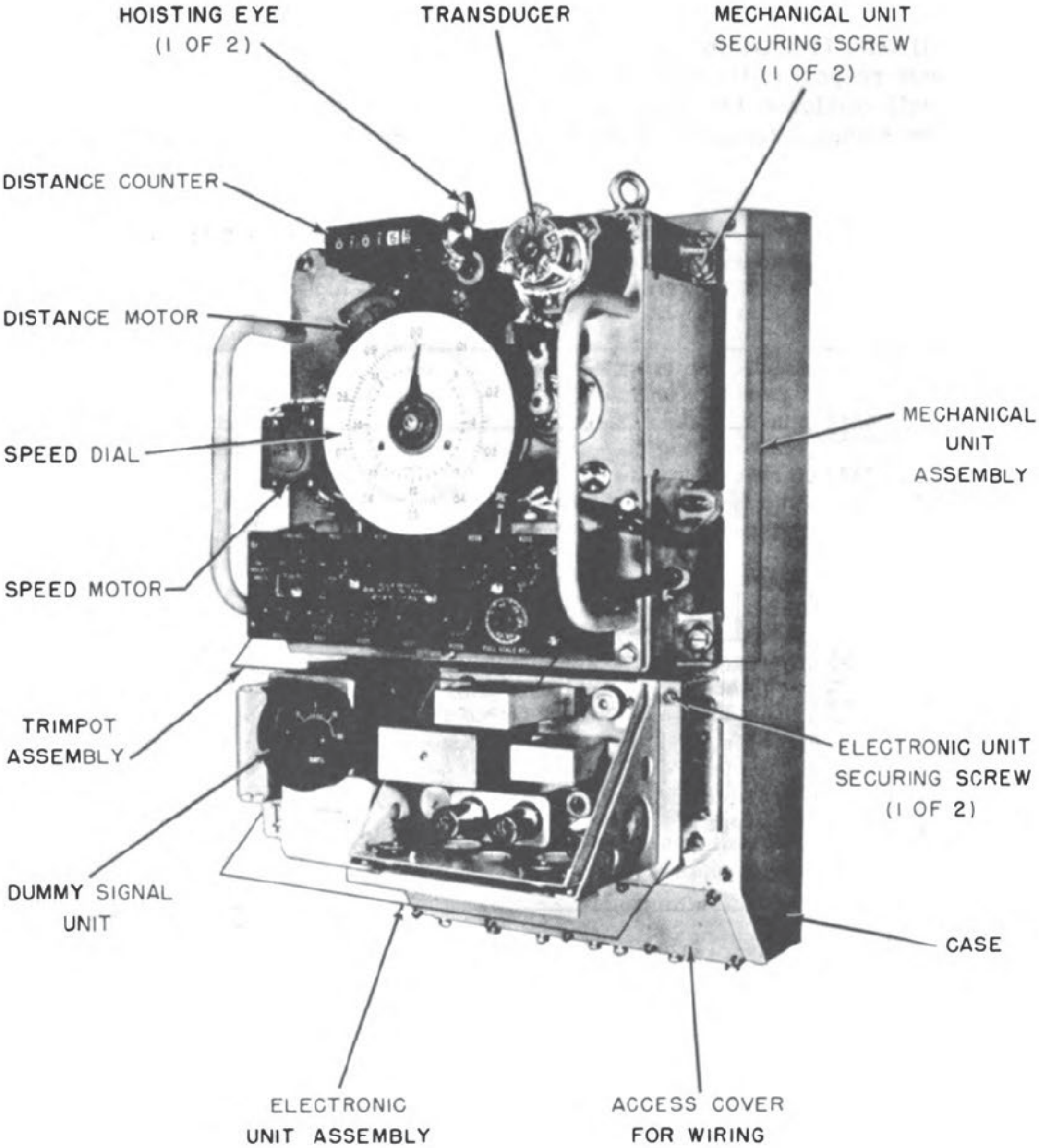


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Figure 12-17.—Indicator-transmitter (cover removed).

voltage drop across R3 will cause the grid of V1B to become more negative with respect to its cathode. This action tends to restrain the plate current in V1B. At the same time the signal is also positive on the grid of V1B and will restrain the plate current in V1A. Thus, the total effect is to suppress the balanced signal.

However, the speed signal produced by the rodmeter is an unbalanced signal. A balanced voltage that reaches the grids of the first amplifier stage may be noise or some other undesirable signal. An unbalanced signal develops opposite polarities on the grids of V1A and V1B and this signal is amplified instead of suppressed. Consider a signal that tends to

drive the grid of V1A positive and the grid of V1B negative. The increased plate current through V1A will tend to make the grid of V1B more negative with respect to its cathode. This action in turn will reinforce the effect of the incoming negative signal to the grid. Thus, the amplifier will magnify incoming unbalanced speed signals and suppress incoming undesirable balanced signals.

The unbypassed 100 K-ohm resistor R1 between the junction of R2, R3, R4, and ground, provides degeneration for any signal which is in

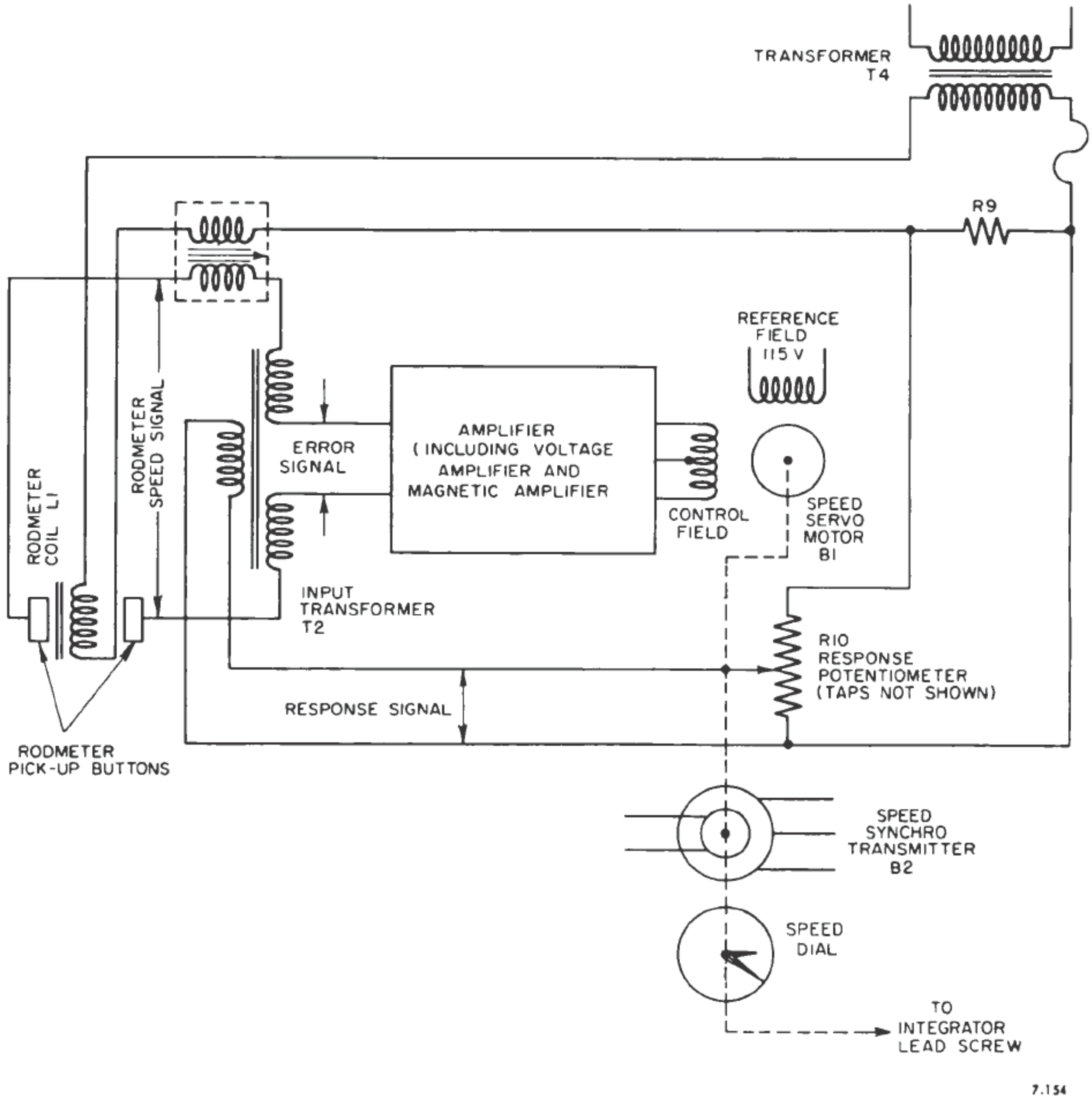

Figure 12-18.—Block diagram of speed servo.

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ıase on both grids to ground. The capacitor ›twork Z3 reduces high frequency response in e amplifier and improves the stability of the :rvo.

ƆWER SUPPLY.—The power supply (fig. 12-) to the voltage amplifier consists of power ansformer T3, rectifier CR3, inductor L2, and ›sistor network Z2. The primary of T3 is ccited from the ship's 115-volt 60-cycle power. he 5-6 secondary winding furnishes 6.3 volts to .e filaments of AR2, AR3, and Z2 which are .e second, third, and fourth stages, respec-vely, of the voltage amplifier. The 3-4 second-:y winding supplies 380 volts to the filtering ıd regulating networks for the plate supply. he 7-8-9 winding supplies the current to the ›ctifier and filter circuit for the filaments of ıe first stage amplifier AR1.

The filtered d-c for the filament of the first ɔltage amplifier AR1 is supplied through the ıll-wave rectifier CR1-CR2 and choke L3.

The plate current is supplied through the ıll-wave bridge rectifier CR3 and the LC lter network consisting of L2 and C3. Part of ıe plate current goes to the fourth stage of 3A of the voltage amplifier via transformer '5. The remainder of the plate current goes ırough the filtering-decoupling network Z1. 'rom Z1, part of the plate supply goes to V1A nd V1B of the voltage amplifier and the other art goes to the third stage V2.

The gas regulator tubes V4 and V5, across ıe filtered plate supply keep the plate supply oltage at a constant level irrespective of hanges in the line voltage and of fluctuations in ıe plate circuit impedance due to signal changes.

The magnetic power amplifier AR4 is a -stage, half-wave self-saturating unit. The ıput to this is from the last stage Z2 of the oltage amplifier via the output transformer '5, which matches the push-pull voltage am-lifier to the single-end input of AR4. The output f AR4 is fed to the control field of the 2-phase, apacitor-type speed servomotor B1.

The power supply input is through header ›rminals 1-2 and the signal input is through erminals 6-7 from the secondary of T5. The ;ain control R8 is not shown. The balancing :ircuit is through terminals 9-10 which are :onnected to the balancing potentiometer R5. The balancing circuit functions to adjust the amplifier so that it yields zero output for zero signal. Should the amplifier become unbalanced and develop outputs that do not correspond with the input signal, careful adjustment of the bal-ancing control will eliminate this unbalance.

The amplifier output goes through header terminals 4 and 5 to the motor control field windings. The feedback connection is through resistors R6, R7, and terminal 11.

SERVO MOTOR.—The speed servo is driven by a small two-phase squirrel-cage induction motor B1, of the capacitor type. Its field consists of two sets of windings as shown in figure 12-20. One is a single reference winding. The other, the control winding, actually consists of two separate coils. The reference and control windings are arranged at an angle of 90 degrees with respect to each other.

The amplifiers output at inputs other than zero is a pulsating d-c (pulses at 60 cps) through either one control winding coil or the other. This develops a 60-cps a-c in the resonant tuned circuit which includes the two control field coils and capacitor C4. When one of the coils is excited by amplifier output, the a-c in the field is in phase with the reference (power) supply; when the other coil is excited, the a-c in the field is 180 degrees out-of-phase with the reference supply. This phase relationship is ultimately determined by the input received from the voltage amplifier through T5.

The reference winding is fed from the a-c reference supply. Capacitor C5, in series with this winding displaces its current through 90 degrees. Thus, since the control winding is either in phase with the reference supply or 180 degrees out, the direction in which the rotor turns depends on whether the control field flux leads or lags the reference field flux.

The motor drives the speed dial, speed synchro transmitter B2, and response potenti-ometer R10.

RESPONSE CIRCUIT.—A simplified schematic of the response circuit is shown in figure 12-21. Power is supplied to response circuits by the voltage drop across R9. Since this resistor is in series with the rodmeter coil, the voltage across R9 is in phase with the coil current. Therefore the response signal is in phase with the speed signal. It is algebraically added to the speed signal from the rodmeter in the input transformer. The algebraic sum, or error signal, is the input to the amplifier, as described earlier.

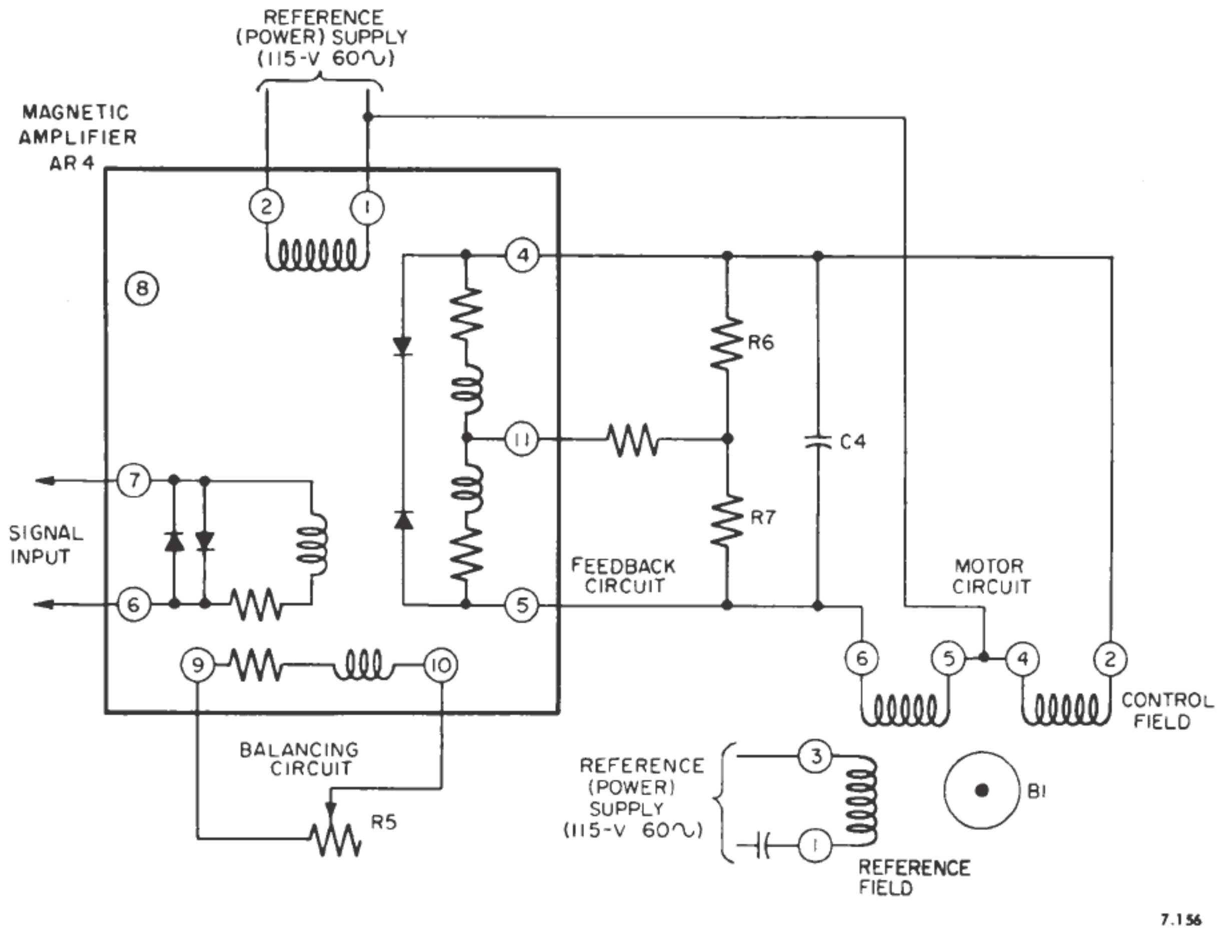

Figure 12-20.—Schematic diagram of magnetic amplifier heading speed servo motor, and balance circuit.

DIAL AND SPEED SYNCHRO TRANSMITTER.—Ship speed as transmitted by the speed servo is indicated on a dial on the face of the indicator-transmitter. The dial is a clock-type indicator with the short hand making one complete revolution for change in speed of 40 knots, and the long hand making one complete revolution for a change in speed of 1 knot. The hands are driven through gearing by the speed servo motor. The servo motor also positions the rotor in the speed synchro transmitter.

Integrator

The integrator uses the speed servo output to develop a continuous shaft rotation proportional to ship speed. The integrator consists of:

1. A smooth disk rotated at constant speed by a synchronous time rotor.
2. A wheel or roller driven by friction contact with the surface of the disk.
3. A nonrotating lead screw which can position the wheel at any required distance, within limits, from the center of the disk.
4. A threaded bushing, driven by the speed servo motor, which engages the lead screw and translates it longitudinally when it rotates.

The wheel's rate of rotation depends on (1) the rotational rate of the disk, which is constant, and (2) the wheel's distance from the center of the disk, which is regulated by the position of the screw. The screw, when translated by the rotation of the speed servo-driven bushing, moves the wheel toward the disk's center as the speed goes down, or toward the disk's

periphery as speed increases. The number of rotations made by the wheel is thus proportional to the distance the ship travels through the water. To keep the wheel from causing excessive wear on the disk at zero speed, the zero position of the wheel is at a radius of 0.5 inch from the center of the disk. Thus, the wheel is always in rolling contact with the disk, and it rotates even when the ship's speed is zero. At zero knots the wheel rotates at 200 rpm.

The function of the differential is to cancel out this continuous wheel rotation at zero speed. Wheel rotation drives one end gear of the differential. The time motor drives the other end gear. At zero ship's speed (wheel at minimum distance from the center of the disk) the inputs to the two end gears of the differential are equal, and opposite in direction.

Since the minimum distance from disk center permitted for the wheel corresponds to zero speed output from the speed servo, the equipment can register only positive (forward) increments of distance.

Distance Servo

The integrator output is a continuous rotation at a rate proportional to ship's speed. This output is used to drive a miles counter and a synchro transmitter which transmits a corresponding sychro signal to remote receivers. However, because a direct load on the integrator output is likely to cause slippage, wear, and inaccuracy a distance servo receives the integrator output. The distance servo in turn drives the counter and synchro.

The main components of the distance servo are:

1. Mechanical differential
2. Transducer
3. Demodulator
4. Saturable transformer
5. Servo motor
6. Counter
7. Distance synchro transmitter

DIFFERENTIAL.—The mechanical differential functions as an error-detecting device. It receives two inputs—the speed signal output from the differential in the integrator, and the

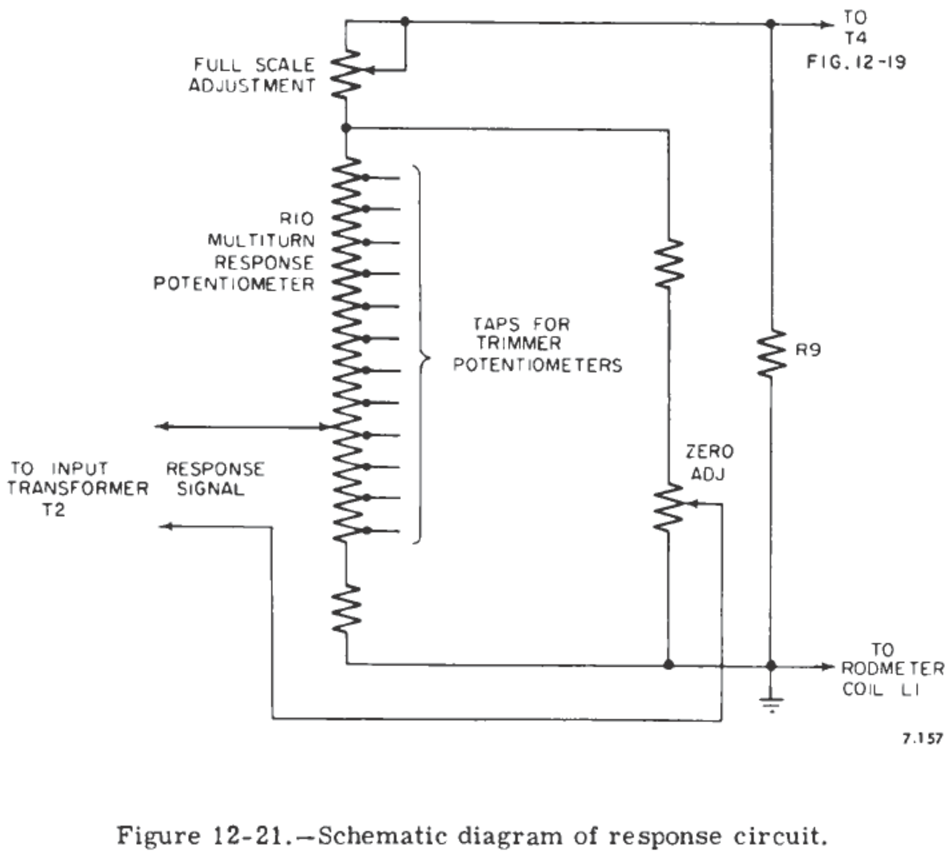

Figure 12-21.—Schematic diagram of response circuit.

mechanical response from the servo motor. Its output is an error signal which turns the shaft of the transducer.

TRANSDUCER.—The transducer (fig. 12-22) or pick-off unit is a rotory device that functions like a variable transformer. It is actually a standard Navy size 1G 115-volt 60-cps synchro transmitter. R1 and R2 are excited by the 115-volt reference supply. The voltage output from the stator depends upon the rotor position and the output voltage is tapped from terminals S1 and S2 (S3 is not used). This voltage is then amplified. Thus, the transducer converts the mechanical motion received from the differential into a voltage which it transmits to the demodulator and saturable transformer. Its output thus controls the distance servo motor.

DEMODULATOR AND SATURABLE TRANSFORMER.—The output from the transducer (fig. 12-22) is an a-c signal whose phase relationship with respect to the reference supply depends on the angular position of the rotor (excited by the reference supply) and the stator. The saturable transformer functions like a single-stage magnetic amplifier.

The saturable transformer requires a d-c control signal. The function of the demodulator is to furnish such a signal.

The demodulator is a phase sensitive rectifier device. Figure 12-23 is a schematic diagram of the demodulator, the signal source (the transducer secondary), the reference supply (115-volt 60-cps), and the output to the control windings of the saturable transformer.

As the diagram shows, the demodulator is fundamentally a bridge-type rectifier circuit consisting of four rectifiers. The a-c signal input comes from the transducer. The reference supply allows the rectifiers to pass current during one-half of its cycle, and causes them to block current flow during the other half.

The transducer, as mentioned, functions like a rotary variable transformer. Depending on rotor position with respect to the stator, the input it supplies is either in phase with the reference supply or 180 degrees out. If the transducer signal is in phase all rectifiers will conduct during one-half the cycle and signal current will flow in one direction. However, during the other half of the cycle no current would flow.

If the transducer output reverses phase (as it would if its shaft were driven in the opposite direction), then current would flow in the control windings in the reverse direction during that part of the reference supply cycle when

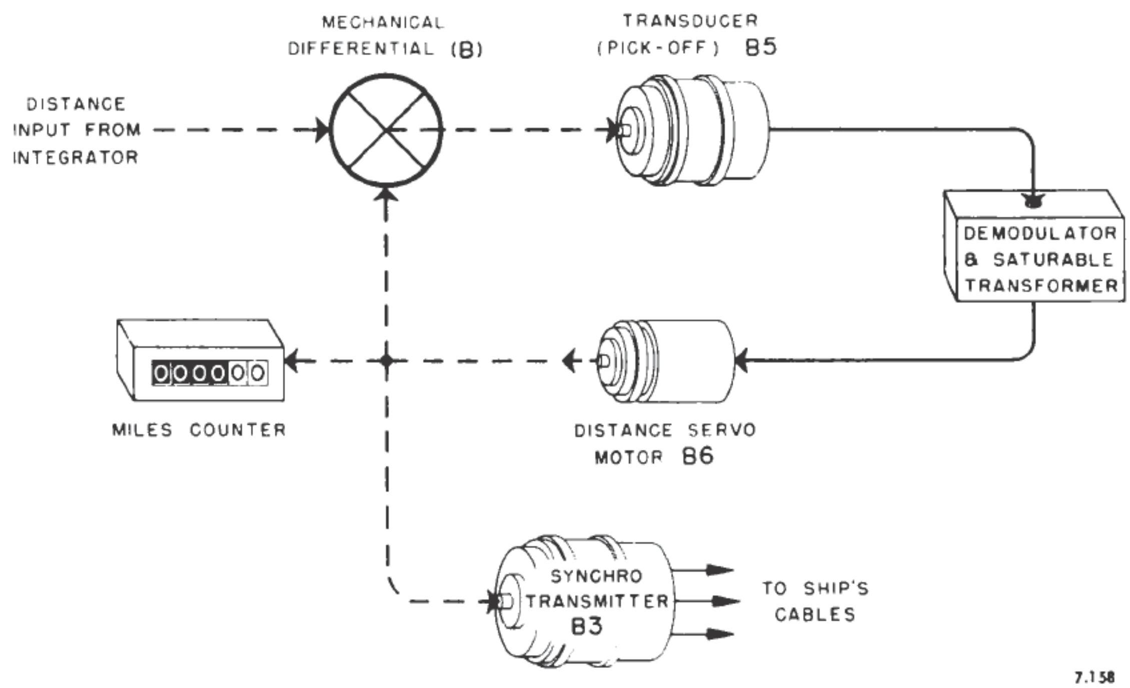

Figure 12-22.—Functional schematic diagram of distance servo.

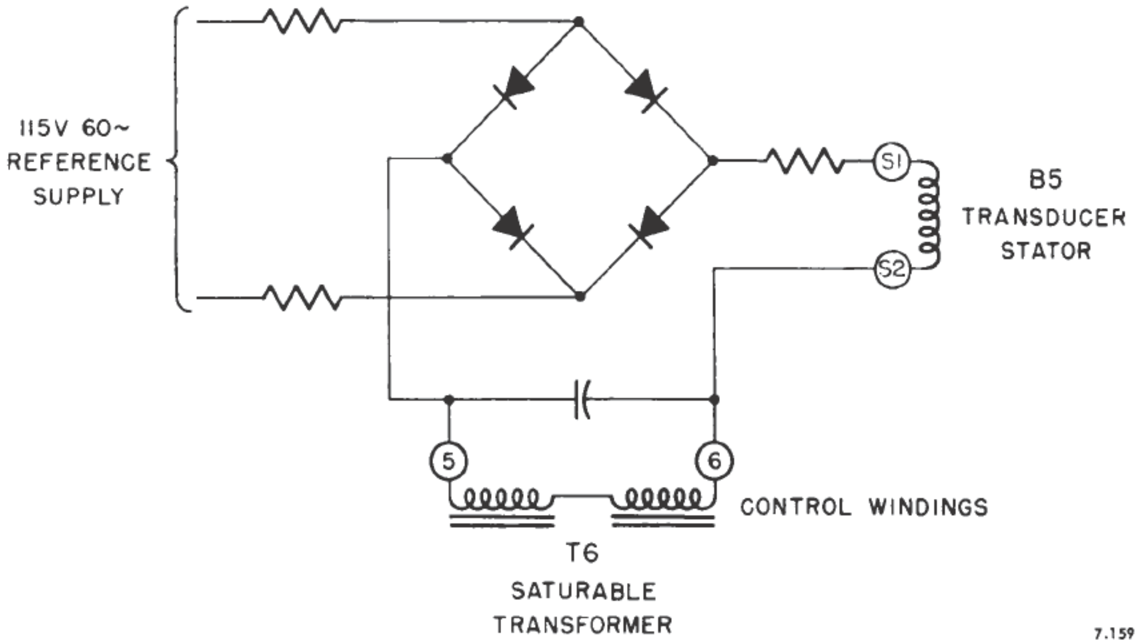

Figure 12-23.—Schematic diagram of demodulator. Distance servo.

current is permitted to flow in the demodulator.

The saturable transformer is a variable-impedance transformer. The impedance is varied by a d-c control current from the demodulator. The assembly contains two transformer cores of the shell type (fig. 12-24). Each core is wound similarly, with four windings: d-c bias, d-c control, a-c primary, and a-c secondary. The a-c windings are distributed on the outer legs of the core; the d-c windings are on the center legs of the core. This arrangement minimizes transformer coupling from the a-c to the d-c windings. The secondaries on the two cores are connected so that the output voltage of one is in phase opposition to that of the other. When the impedances of the cores are equal, secondary output voltage is zero.

The saturable transformer receives two d-c inputs—the variable signal from the demodulator and the fixed bias current from full-wave rectifier. The bias current establishes an initial d-c magnetization level in each core.

The bias and control windings are so interconnected that when current flows in the control winding, the flux generated by the current adds to the bias flux in one core and opposes the bias flux in the other. Thus, a control current in either direction drives one core further into saturation, and drives the other out of saturation. The greater the control current, the greater is the difference in saturation of the cores. The greater the saturation, the lesser is the amount of flux available in the core to cause induction in the secondary by transformer actions, and the lesser is the output voltage. Thus, the less saturated core produces the higher output voltage.

The output of the saturable transformer is substantially the difference between the output voltages of the two secondary windings (one on each core), and is the same phase as the voltage across the winding but has a higher output. The transformer output is always phase shifted about 90 degrees from the reference supply, but may either lag or lead, depending on the direction of the control current.

SERVO MOTOR AND SYNCHRO TRANSMITTER

The distance servo motor and distance synchro transmitter are similar to those used in the speed servo discussed earlier in this chapter. The synchro rotor is fed by the 115-volt 60-cps synchro reference supply; the synchro stator feeds a 3-wire transmission line to

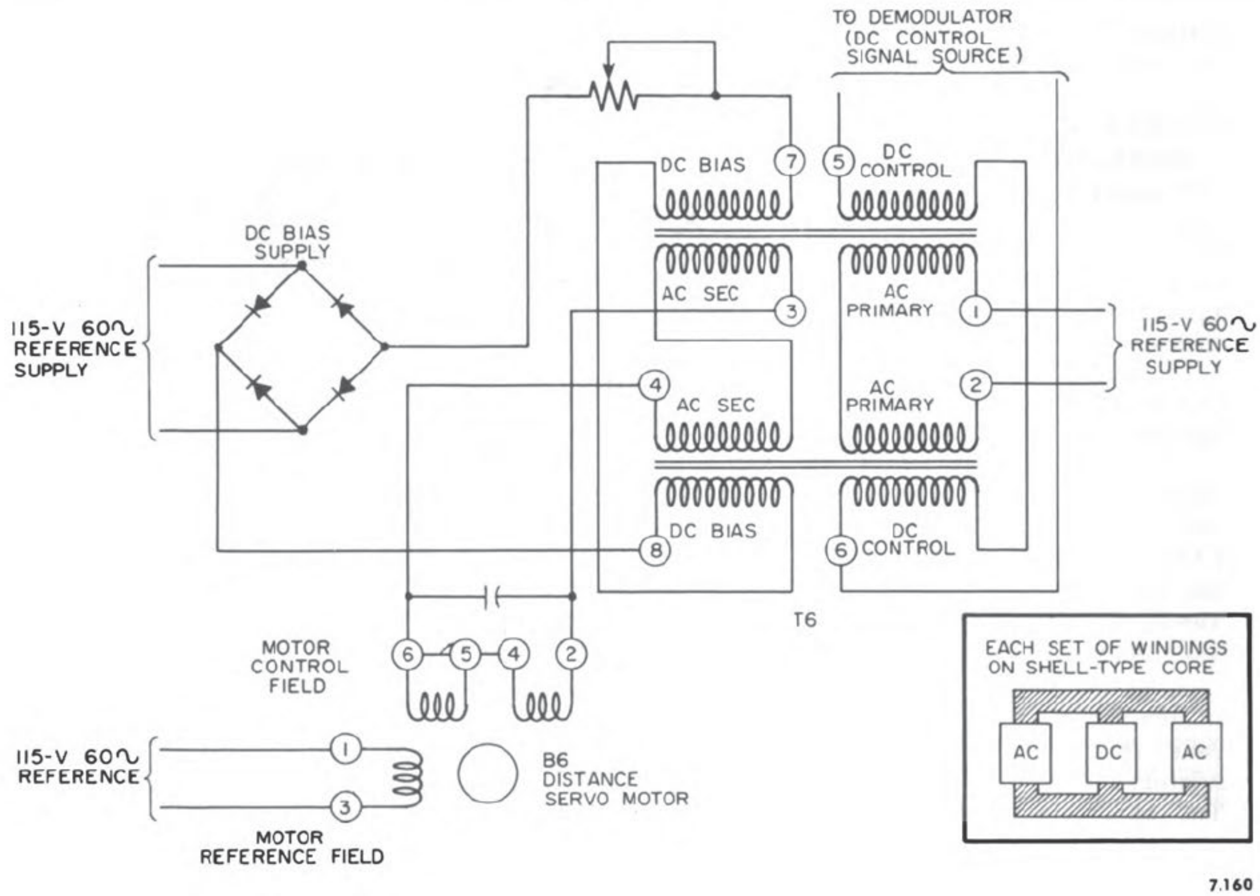

Figure 12-24.—Schematic diagram of saturable transformer. Distance servo.

remote stations where the distance information is used.

COUNTER

The distance counter is a 6-phase commercial type unit that registers to 0.01 nautical mile. Maximum indication is 9,999.99 nautical miles. A reset knob permits turning the counter back to zero if necessary. The counter receives the continuous rotational speed signal from the distance servo, and records cumulatively the number of turns (corresponding to distance traveled) it has received since it was last at zero.

DUMMY SIGNAL CIRCUIT

The function of the dummy signal circuit is to produce voltage signals which simulate speed outputs from the rodmeter. Such signals can be used to check the performance of the distance servo. The dummy signal circuit provides a simulated response signal that causes the speed servo to stabilize at any of four dial readings (0, 5, 15, or 30 knots), and permits measurement of the accuracy of distance servo and integrator functioning. Dummy signals are not intended for calibration purposes, but only to check functioning of the equipment.

QUIZ

1. What does the shaft revolution indicator system indicate?
2. What do the indicator-transmitters installed at the throttle station convert?
3. How is the relative direction of the speed indicated?
4. What kind of a device is the speed-measuring mechanism?
5. When the input gear 118 and the helical gear 32 (fig. 12-4) are running at exactly the same speed, what is the status of the contacts and followup motor 9?
6. What keeps the pointers from reaching the exact scale zero?
7. In the magneto-voltmeter type equipment, what is the function of the magneto?
8. What is the purpose of the unidirectional mechanism?
9. What type of meter is used with the indicator for the shaft revolution unit?
10. What converts the wind speed into rotary motion in a wind direction and speed indicator system?
11. Why is the wind direction synchro transmitter set to electrical zero when the rotor assembly of the detector unit points to the bow of the ship?
12. In a wind direction transmitter, when is the output of the CT zero?
13. What happens to the signal from the CT (fig. 12-8)?
14. How are the transistors TR1-TR2 and TR3-TR4 connected in the wind transmitter (fig. 12-8)?
15. What is the function of the followup motor in the wind direction system?
16. In the wind direction system, what restricts the direction of current flow in the transistors and control windings?
17. In the wind speed subassembly, on what does the speed of the circular motion of the drive roller depend?
18. When is the 5HG synchro transmitter set to electrical zero in the wind speed unit?
19. What is the purpose of the salinity indicator?
20. Upon what principle is the salinity indicator system based?
21. In what units are the scales of salinity meters?
22. Of what does a complete salinity indicator system consist?
23. What makes up the electrode assembly?
24. What is the indication of a high salinity condition?
25. In the salinity system, what determines the grid to cathode voltage of V1 (fig. 12-13)?
26. What are the various types of underwater log equipments?
27. Of what does the electromagnetic-type underwater log consist?
28. In an electromagnetic log system what drives the speed synchro transmitter?
29. What is the function of T2?
30. What is the purpose of the unbypassed 100 K-ohm resistor R1 in figure 12-19?
31. Where does the d-c for the filaments of AR1 come from?
32. What type of unit is AR4 (fig. 12-19)?
33. What drives the servo motor B1 in figure 12-20?
34. What is the purpose of the integrator?
35. What is the function of the transducer (fig. 12-22)?
36. What type of rectifier circuit does the demodulator in figure 12-23 have?
37. Why are the a-c windings distributed on the outer legs of the core (fig. 12-24)?

CHAPTER 13

THE MAGNESYN COMPASS

INTRODUCTION

I.C. Electrician 2 is required to service and perform preventive maintenance on a variety of shipboard I-C components, one of which is the Magnesyn compass. Although the gyrocompass (described in the next chapter) is standard equipment on all naval vessels, it is supplemented by the magnetic compass. A special type of magnetic compass (described in this chapter) called the remote indicating Magnesyn compass system is used on many naval vessels, principally those with steering control consoles, and on older type landing craft.

COMPONENTS

The Magnesyn compass system comprises a transmitter composed of a "blind" compass mounted in a position as free as possible from magnetic disturbances, and one or more indicators (fig. 13-1) which reproduce movements of the compass magnet in the transmitter. They are installed in a location convenient to the helmsman, and sometimes in the secondary conning station.

Magnetic materials near the indicator will not affect the accuracy of the Magnesyn compass system. Such disturbances must be avoided only in the neighborhood of the transmitter.

An inverter for changing d-c from batteries to 400-cps a-c for operation of the system is mounted in a waterproof box which may serve as a junction box for all connecting cables. A 120/26-volt 400-cycle stepdown transformer provides the normal power supply for the system on ships other than landing craft. A selenium rectifier is furnished for charging the battery. The input to the rectifier is 117-volt 60-cycle single-phase power and the output of the rectifier is 12-volt d-c power at 2 amperes.

The transmission of the magnetic indications of the compass to the indicator is entirely electrical. The only moving parts in the system are in the inverter, the compass float assembly, and the indicator rotor.

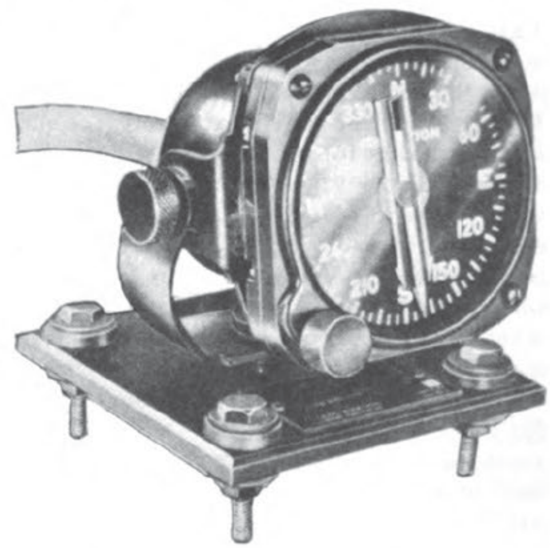

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Figure 13-1.—Magnesyn compass indicator.

THEORY OF OPERATION

In order to understand the principle of operation of the Magnesyn compass we will review briefly the characteristics of a magnet, the magnetic properties of the earth, and the problems involved with the conventional magnetic compass.

A magnet has magnetic lines of force which surround it, extending outward from the north pole and entering at the south pole to form closed loops. These lines of force are associated with the familiar attraction of unlike poles and the repulsion of like poles (refer to *Basic Electricity*). When no other magnetic material is near, the lines of force form a symmetrical pattern around the magnet. When a piece of soft iron is placed near the magnet, most of the lines of force will pass through the piece of soft iron because soft iron is a good conductor of magnetic lines of force and offers lower reluctance than that of air.

The earth is in reality a huge magnet with its "north" pole situated in the Arctic Circle and its

''south'' pole within the Antarctic Circle. Magnetic lines of flux extend from the region of the ''south'' magnetic pole and enter the region of the ''north'' magnetic pole. A compass needle tends to align itself with the earth's magnetic field so that the magnetic lines of flux enter the south pole of the compass needle and extend outward from the north pole. Thus the north pole of the compass needle points toward the ''north'' magnetic pole except when the earth's field is distorted, for example, by the magnetic materials of a ship. (The so-called ''north'' magnetic pole is really a south pole because the lines of force of the earth's field enter it.)

The error to which a ship's magnetic compass is subjected due to the influence of the ship's magnetism is called deviation error. Deviation error is caused by the magnetism of the steel and soft iron parts of the ship and by electrical conductors carrying direct current. Also, the soft iron parts of a ship readily acquire transient magnetism by magnetic induction from the earth's field. The magnetism thus induced in soft iron varies as the ship changes course. The compass deviation error may change as the ship changes course.

MAGNESYN REMOTE INDICATING COMPASS

The locations at which compass readings are most needed are very often in close proximity to the greatest magnetic disturbances. Because of the remote indicating feature of the magnesyn system the transmitting unit can be mounted in a position in the ship where it will be least affected by the magnetic field of the ship itself, and therefore will be free to a very great extent from the effect of deviation. This feature is particularly advantageous where the magnetic field of the ship tends to shift from time to time as a result of changes in position or from the use of armament. The indicator, on the other hand, may be placed anywhere without regard to the ship's magnetic field.

Principle of Electromagnetic Induction

This compass system operates on the principle of electromagnetic induction whereby an electrical voltage is induced in an electrical conductor when it is cut by magnetic lines of flux (fig. 13-2). In this sytem the cores of the transmitter and indicator are saturated twice each cycle when excitation reaches a peak value. At such times, no additional magnetic effects can be produced within the cores. At other times, the cores are free to assume such magnetic characteristics as may be imposed on them. The magnetic field produced by the compass magnet will pass through the core of the transmitter coil when the value of the exciting current falls toward zero. It will be prevented from passing through the core when the core is saturated.

The result of the above action is the induction of a magnetic flux in the core of the transmitter coil between points opposite the poles of the compass magnet. This flux rises and falls and is superimposed on the flux produced by the exciting current. The ebb and flow of this magnetic flux sets up, at the four take-off points, alternating voltages the values of which are dependent on the position of the compass magnet with respect to the transmitter coil. Since the four points of the transmitter coil are directly connected to four similar points of the indicator coil, any potential difference between connected points causes a current flow in the indicator coil so as to equalize the voltages between the two coils. This current flow through the windings of the indicator is superimposed on and independent of the flow of the indicator excitation current.

The secondary currents produce their own magnetic effects within the core of the indicator, and since the indicator rotor magnet is shielded from the earth's magnetic field and free to revolve, it follows the rotation of the transmitter magnet.

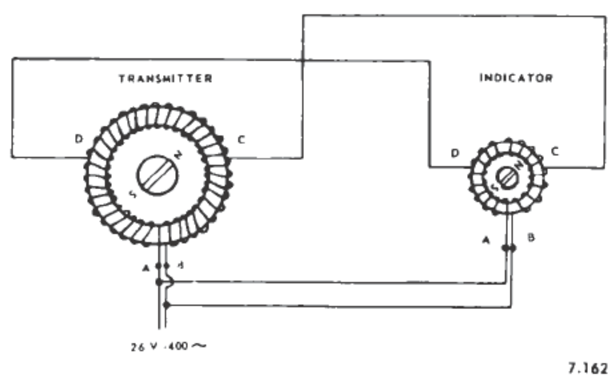

Figure 13-2.—Principle of electromagnetic induction.

Any change in the position of the compass magnet in the transmitter, caused by change of heading of the ship, produces a change in the characteristics of both the transmitter and indicator coils, and a corresponding change in position of the rotor magnet of the indicator. Since the indicator pointer is attached to the shaft on which the rotor magnet is mounted, it provides at all times an accurate indication of the position of the compass magnet in the transmitter.

DESCRIPTION OF COMPONENTS

The transmitter consists of a float assembly, a transmitter coil, and a compensator assembly.

TRANSMITTER

The transmitter float assembly (fig. 13-3) is immersed in compass fluid (Varsol) in a smooth-surfaced bowl. The bowl is spherical in shape (fig. 13-3) so that the compass float will, so far as possible, be free of swirl errors, and so that liquid drag will be reduced. To provide for the expansion and contraction of the compass fluid, a diaphragm is incorporated in the bowl. The float is equipped with four damping fins and is pivoted on a single shock mounted jewel, spun in a jewel post. The float contains the directive or compass magnet. The float is free to rotate and to tilt at any angle up to 20 degrees from the horizontal.

The transmitter coil (or flux gate) is mounted directly beneath the compass magnet in the float

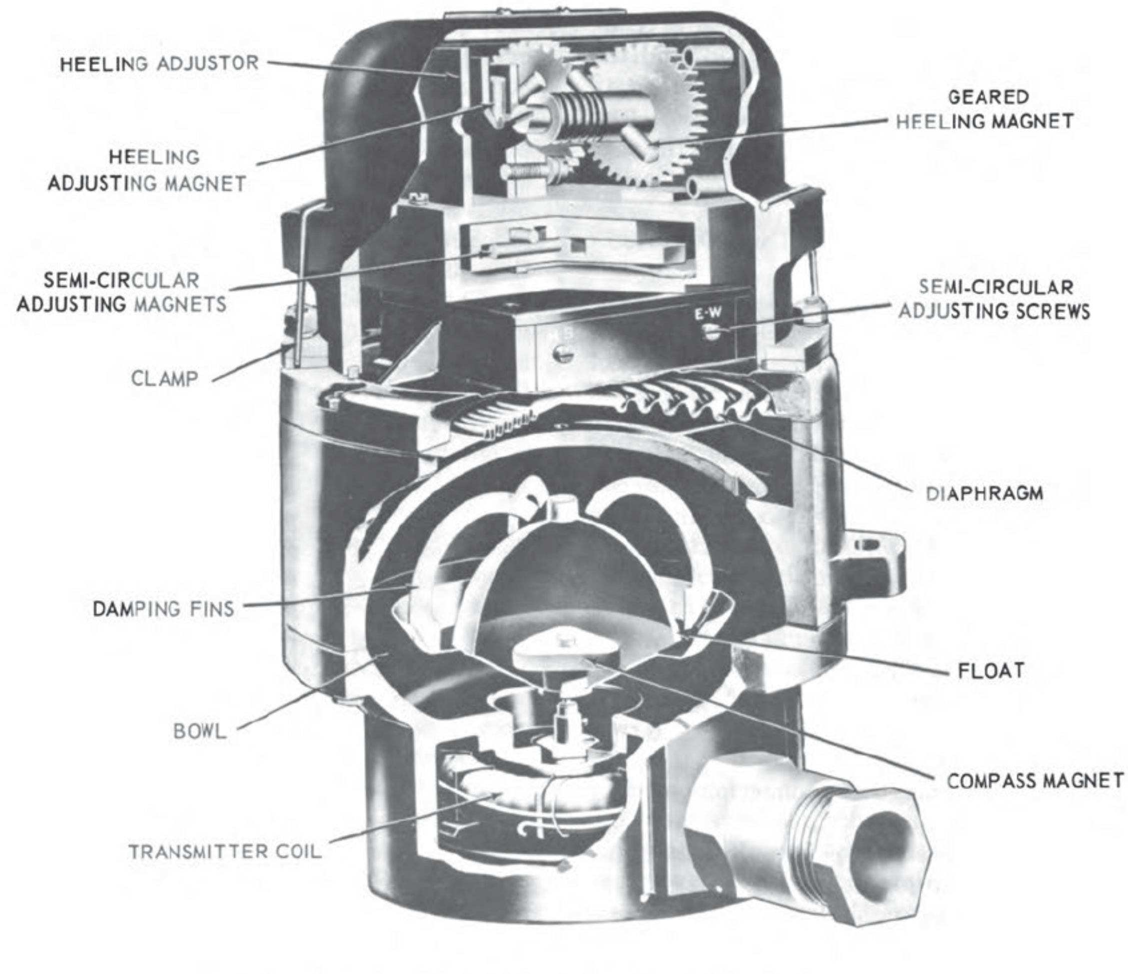

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Figure 13-3.—Magnesyn compass transmitter.

assembly. It consists of high permeability, circular laminations (similar to permalloy) around which is a toroidal winding. Four leads go to the coil. Two of these go to the power supply. The remaining two leads are tapped into the coil so that they are 120 degrees apart and each is 120 degrees from the nearest power lead.

Suitable wiring connections are made so that the transmitter and indicator are connected together in parallel (fig. 13-2).

A universal-type compensator is provided immediately above the transmitting unit. By means of this assembly, corrections may be introduced for heeling errors and semicircular errors (deviation errors) caused by the magnetic field of the ship. For instructions for its use, see NavShips 324-0090.

INDICATOR

The Mark 1 indicator (fig. 13-4) consists of a permanent magnet rotor, a stator assembly, and a return magnetic path enclosed by a case. The Magnesyn case assembly has jeweled bearings in which the shaft of a permanent magnet rotor turns. A pointer is attached to this shaft.

The stator is made up of circular laminations with a toroidal winding. The return path for the flux of the rotor magnet consists of outer laminations that are concentric with the stator. A magnetic shield, which surrounds the brass Magnesyn case, is used to minimize the effect of stray magnetic fields around the indicator. The housing consists of a dusttight, waterproof case for the component parts of the indicator.

A course-setting pointer is provided on the indicator dial and may be adjusted by turning a knob at the lower left-hand corner of the indicator. The indicating pointer, course-setting pointer, dial numerals, and divisions are treated with a luminous material.

When operating without lights, the parallel lines of the course-setting pointer between which the indicating pointer should be held will be helpful to the helmsman in holding his course.

The Mark 3 indicator contains an identical permanent magnet rotor, stator assembly, and Magnesyn case as the Mark 1 indicator; its operation and wiring connections are also identical to the Mark 1 indicator. However, the Mark 3 indicator lacks the course setting pointer, has a larger dial, a longer pointer, and controllable, internal red illumination. This illumination is provided by three 6.3-volt incandescent lamps

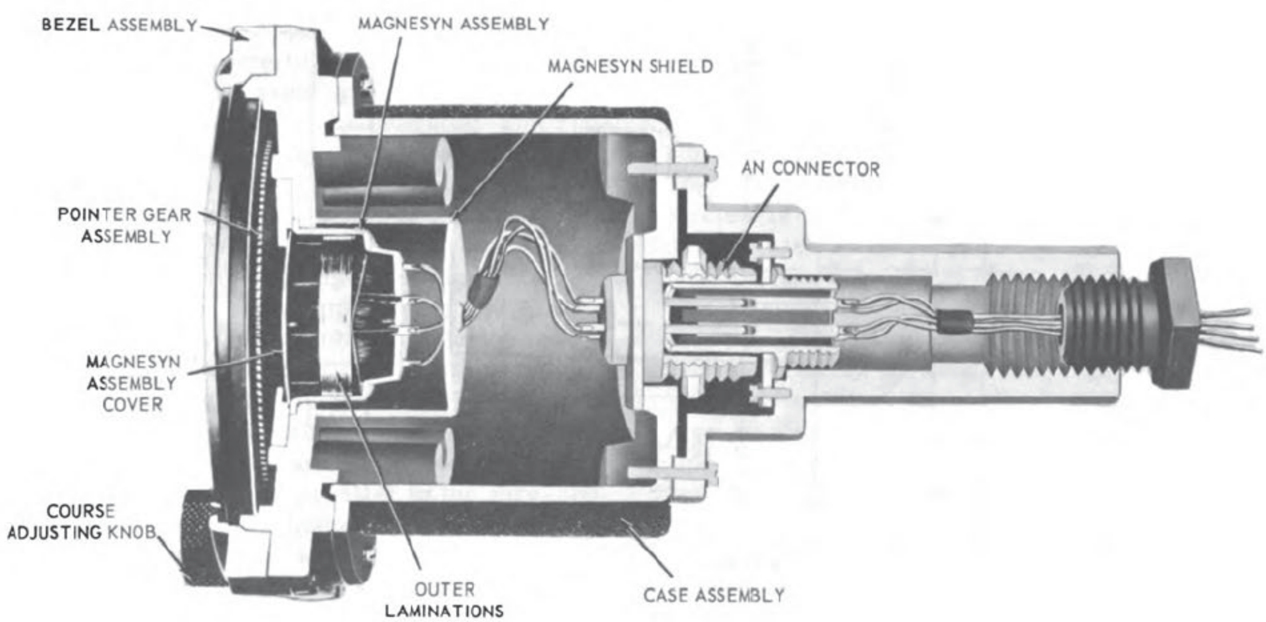

Figure 13-4.—Mark 1 Magnesyn indicator.

supplied via a stepdown transformer mounted in the indicator case. The transformer is energized from the 120-volt ship's lighting system.

INVERTER

The inverter power supply (fig. 13-5) consists of a miniature shunt motor driving a permanent magnet rotor a-c generator. The inverter operates on 12 volts d-c and draws approximately 2 amperes. The a-c output voltage is 26 volts at a frequency of 400 cycles. The speed is 8000 rpm.

The inverter is mounted in a box in such a way that when the cover is removed the brushes are accessible. A low-pass filter is mounted beside the inverter and connected across the commutator to reduce r-f interference to a minimum. Three leads go to the inverter. These are for d-c input, 26-volt a-c output, and a common ground. The leads are connected to appropriate terminals in the inverter box.

INSTALLATION

Although the IC Electrician 2 may seldom be required to install the Magnesyn compass system, it is important that he understand the installation requirements for satisfactory operation. To that end the following information is included in this training course.

In order to obtain accurate performance it is essential that the transmitter be installed in a location having a minimum of magnetic interference. It is advisable to install the transmitter as far as possible from all movable magnetic material such as steel structures, guns, cables, ammunition, and loads which may be taken on and off the ship. It is not possible to adjust for the effects of movable magnetic masses since the disturbances set up will vary with their position. In general, the Bureau of Ships specified a nonmagnetic circle of 6-foot radius for fixed magnetic material and a nonmagnetic circle of 8-foot radius for movable magnetic material around a Magnesyn transmitter.

Care should be taken to avoid the proximity of electric cables carrying direct current, such as power and lighting circuits. Disturbances set up by these circuits are impossible to adjust because their intensity varies with the amount of current.

The transmitter should be located with a test compass (direct reading). The test compass should be mounted in the selected location and

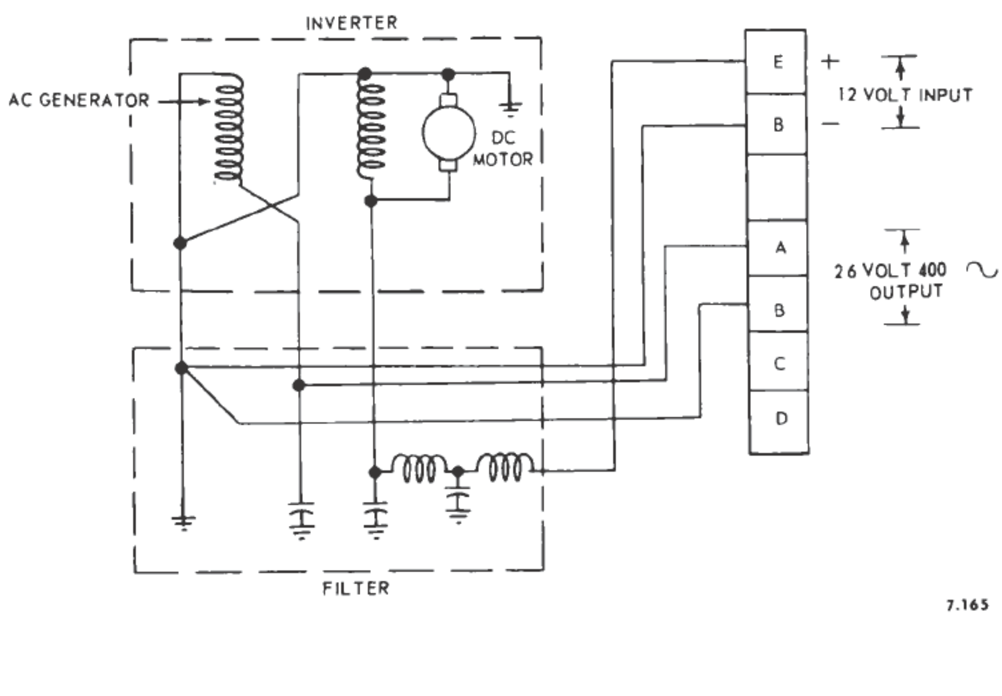

Figure 13-5.—Schematic diagram of inverter.

the effects noted of changes in the position of all movable masses of magnetic material and of switching d-c power on and off in any circuit thought likely to cause interference. The tests should be made on two headings 90 degrees apart. If a change of compass reading occurs on either of the two headings, choose another location and repeat the test for the new position.

Should the flow of d-c power affect the compass and should the location be satisfactory in other respects, it may be possible to eliminate the disturbance by rerouting the d-c cables, or to neutralize the disturbance by using a twisted pair for d-c output and return in place of a single conductor and ground return.

If the location is found to be satisfactory as far as the previously mentioned disturbances are concerned, the ship's navigator should be requested to swing ship and determine if the compass performance is acceptable in the selected location.

The transmitter, so far as the electrical system is concerned, could be mounted at any height. It is desirable, however, to locate it as low as possible to avoid undue swing as the vessel rolls and pitches, and to prevent whip in the mounting structure. In general, the maximum height should not be more than 6 feet above the deck, above the chart house, or above any similar structure which is used for mounting purposes.

The transmitter should be mounted on a rigid nonmagnetic platform to avoid the possibility of its twisting or vibrating in resonance with the engines of the ship. It is essential that nonmagnetic materials such as brass, aluminum, K-monel, and the like, be used for all mounting parts, including screws, washers, bushings, and the metal parts of shock mounts and brackets, so that there will be no magnetic disturbance near the transmitter which might prevent proper adjustment of the instrument or make the resulting adjustment unstable.

The plane of the mounting lugs must be horizontal. The line passing through the center of the cable connector and the center of the rear mounting hole must be parallel to the fore-and-aft axis of the ship. Installation of the transmitter must be made with the cable connector pointing forward. Fine adjustments in alignment may be made by rotating the unit in its mounting slots.

The indicator may be installed in any location convenient to the helmsman. It may be mounted in a vertical or horizontal attitude. However, it should not be mounted within 8 inches of a direct reading magnetic compass.

Additional indicators up to a total of three may be operated from one transmitter. The additional indicators should be connected in parallel with the first indicator. If more than one indicator is used, all compensating adjustments must be made with reference to one of the indicators only. The other indicators must be operating during the procedure. Because of slight differences in their electrical characteristics, individual correction cards will be necessary for each indicator.

The inverter box should be installed not closer than 8 feet from the transmitter or any direct reading magnetic compass, and as near the battery power supply as possible. Free air space should be allowed around the inverter box so that heat may be dissipated. The inverter box should be mounted securely to the ship's structure.

CONNECTIONS AND WIRING

The transmitter and indicator contain similarly wound coils connected as shown in figure 13-2. Power is normally supplied from the 400-cycle bus on the I. C. switchboard via a 120/26-volt stepdown transformer. An emergency supply is also available on some ships. This supply consists of a separate battery, battery charger, and inverter, and is controlled by a switch on the I. C. switchboard. The 12-volt battery and battery charger supply power to the inverter whose output of 26 volts at 400 cycles is applied across terminals A-B of the transmitter and indicator. Additional indicators are installed on some ships. These indicators are normally controlled by a transfer switch in the pilot house so that only two indicators can be energized at the same time.

A pictorial of the wiring in a typical installation is illustrated in figure 13-6. Refer to the applicable BuShips drawing for your ship's particular installation which may differ in details. Care must be taken to avoid reversing the leads between the transmitter and the indicator. Such a reversal might cause failure of the system and serious damage to the instrument. All connections must be securely made. The lead from the hot side of the battery must be connected to terminal E and the lead from the other grounded

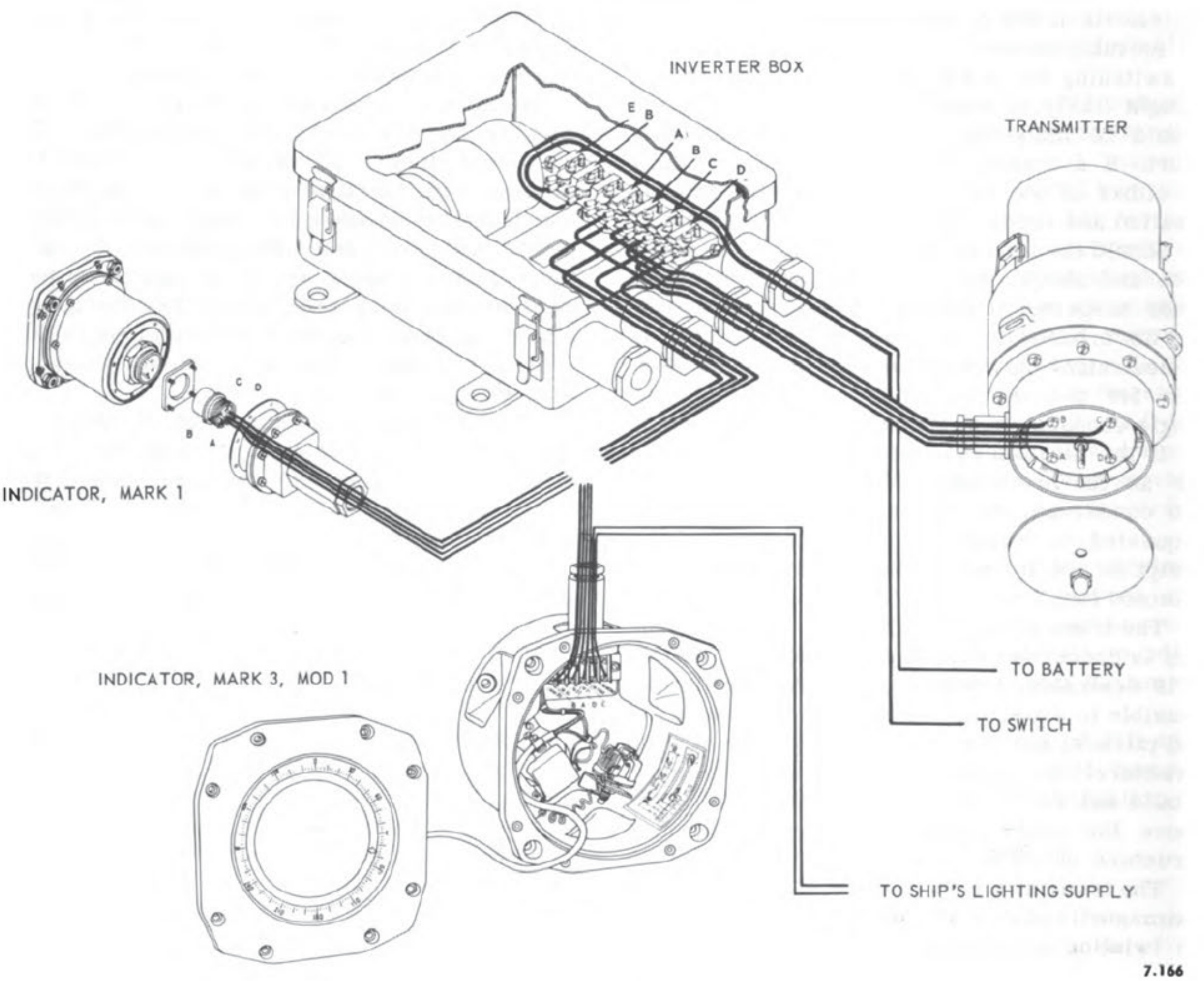

Figure 13-6.—Pictorial wiring diagram of remote indicating compass system.

side to terminal B in the inverter box. Note that the common a-c—d-c lead of the inverter is already connected to terminal B in the inverter box and that the hot a-c lead is connected to terminal A.

Before energizing the system, all connections should be checked carefully. Failure to make connections correctly, or through error, to supply the transmitter, the indicator, or the a-c terminal of the inverter with d-c power will cause serious damage to the instrument.

When connecting cable leads to terminals in the transmitter, care must be exercised to prevent the fine wiring leading from the terminal posts to the transmitter coil from being broken or disturbed. Guard against striking the coil itself or subjecting it to any stress. Strain on the laminations around which the coil is wound will affect the accuracy of the instrument.

SERVICE

Whenever the ship gets underway, the Magnesyn system should be checked for erratic or sluggish operation. If either of the above occur, reference should be made to paragraph on Mechanical Troubles.

PERIODIC INSPECTION

At the end of each 500 hours of operation, the inverter should be inspected for brush wear. Unscrew the brush caps and remove the brush assemblies. Mark the brushes so that they may be put back in the same position after being cleaned and inspected. Replace the brushes if they are worn and spring pressure is weak. Refer to applicable instruction book for details of proper spring pressure, method of replacing brushes, and so on.

Check the condition of the commutator. Clean it with a dry cloth. If it is rough or pitted, polish it, using 000 sandpaper.

On ships employing a battery charger for the Magnesyn system battery, the battery and charger should be checked to determine that a trickle charge is maintained and the battery fully charged.

MECHANICAL TROUBLES

If excessive oscillation or other erratic operation is noted, insufficient liquid in the transmitter bowl or a loose pointer in the indicator may be suspected. Examine the transmitter for leakage of compass liquid by removing the filling cap on the opposite side from the stuffing tube and viewing the level of liquid. If additional liquid is required, a corroded diaphragm may be at fault. This may be determined by inverting the transmitter and observing if there is leakage of fluid from the gauge hole located under the magnet compensator assembly. If the diaphragm is faulty, a new unit should be requisitioned from stock, or the old unit overhauled by an authorized repair activity. If the diaphragm is not faulty, refill the float chamber with compass fluid (Varsol).

If a defective indicator is suspected, replace the indicator with the portable spare unit provided each ship for transmitter adjusting purposes.

Special care should be taken to prevent the battery input from becoming accidentally connected to output terminal A of the inverter. The effect might be to demagnetize the permanent magnet rotor of the a-c generator rotor on the inverter, resulting in greatly reduced a-c output voltage.

If it is necessary to replace a transmitter or an indicator, follow the instructions outlined for their original installation. Slight differences in each instrument will call for adjustments (swinging the ship) and a new correction card.

When replacing a transmitter, readjustment of the compass is essential because the transmitter carries the whole compensating assembly. It would not be practicable to switch compensating assemblies on the units to avoid readjustment of the compass.

SUMMARY

As an aid in locating errors in wiring, table 13-1 shows possible wiring faults. Indicator behavior is considered as referred to a transmitter on a north magnetic heading. Letters refer to wires corresponding to terminal markings anywhere in the circuit. The causes starred with an asterisk (*) will result in the application of excessive voltage to a part of the transmitter or indicator windings. This may affect the calibration of the instrument. Therefore if such a condition is found and the condition corrected, the ship should be swung and readings of the compass checked at the 12 headings on the compass correction card as described in the instruction book for the Magnesyn compass.

Slight errors indicate changes in deviation caused by changes in the magnetic characteristics of the ship. Large errors or the failure of the compass to follow through a turn indicate instrument damage. It is probable that only the indicator is affected in this case; therefore, replace this unit first. Then swing the ship a second time and check the performance of the compass before replacing the transmitter also.

As a final precaution remember that excessive voltage will seriously damage the instrument. Make sure that the d-c voltage input does not vary more than ±20 percent of the rated voltage. Also remember that d-c instead of the 26-volt 400-cps a-c will destroy the instrument, and that d-c applied to the a-c leads of the inverter will damage it.

Table 13-1.—Wiring Faults
(Refer to figure 13-6.)

	Trouble		Probable Cause
1.	No rotation.	1.	A shorted to B.
		2.	Power supply not operating.
2.	Reversed rotation.	1.	A and B reversed and C and D reversed.
3.	Erratic operation in the 90° arc between 330° and 60°.	1.	C open.
4.	Erratic operation in the 90° arc between 300° and 30°.	1.	D open.
5.	Pointer takes either 30° position or 210° position and will not revolve with rotation of transmitter.	1.	A open (power supply reaching one unit).
		2.	D shorted to A or B.*
		3.	A-D phase open in either transmitter or indicator.
		4.	A and D reversed.
6.	Pointer takes either 330° or 150° position.	1.	B open (power supply reaching one unit).
		2.	C shorted to A or B.*
		3.	B-C phase open in either transmitter or indicator coils.
		4.	B and C reversed.*
7.	Erratic operation in the 120° arc between 300° and 60°.	1.	C-D phase open in either transmitter or indicator coils.
8.	Pointer takes either 0° position or 180° position.	1.	A and C reversed with B and D reversed.*
		2.	A and D reversed with B and C reversed.*
9.	Pointer takes either 60° or 240° position.	1.	A and C reversed.*
10.	Pointer takes either 120° or 300° position.	1.	B and D reversed.*
11.	Pointer takes either 90° position or 270° position.	1.	C shorted to D.*
		2.	C and D reversed.
		3.	A and B reversed.

*Asterisks are explained in the text.

QUIZ

1. Does the Magnesyn compass system use a gyro or a magnet as its north indicating element?
2. Why is the earth's "north" magnetic pole really a south pole when the lines of force of the earth's field are considered?
3. What is the compass error that is caused by the ship's magnetism called?
4. What is the underlying principle of operation of the Magnesyn remote compass system?
5. How are the magnitudes of the a-c voltages across the three sections of the stator windings related to the movement of the permanent magnet rotor?
6. When there is a change in the relative position of the rotor and stator of the transmitter, what action causes the indicator to follow this movement?
7. What component in the indicator provides a return path for the rotor flux and at the same time shields the unit from nearby stray fields?
8. Where is the transmitter coil (flux gate) located with respect to the transmitter compass magnet in the float assembly (fig. 13-3)?
9. Are the transmitter and indicator coils connected in series or in parallel?
10. What component of the indicator, in addition to the annular core around the stator, provides magnetic shielding (fig. 13-4)?
11. How is the 26-volt 400-cps supply derived?
12. Where should the transmitter be installed with respect to locations having magnetic interference?
13. What component should be used to facilitate locating the transmitter unit?
14. Why is it desirable to locate the transmitter as low as possible even though as far as the electrical system is concerned it could be mounted at any height?
15. How may fine adjustments in transmitter alignment be made?
16. How many indicators may be used with one transmitter?
17. Why must care be taken to avoid reversing the leads between the transmitter and the indicator?
18. How often should the Magnesyn system be checked for erratic or sluggish operation?
19. How often should the inverter be removed for inspection, and overhauled if necessary?
20. Why should special care be taken to prevent the battery input from becoming accidentally connected to output terminal A of the inverter (fig. 13-6)?

CHAPTER 14

THE GYROCOMPASS

A shipboard gyrocompass installation provided with an electronic control system (to make it seek and indicate true north) is described in this chapter. The basic theory and principles of the gyrocompass system are described in *I. C. Electrician 3*, NavPers 10555-A.

The Mark 23 Mod 0 gyrocompass system (figs. 14-1 and 2) consists of a master unit (fig. 14-3), control cabinet, speed unit, alarm control, alarm bells and annunciators. The system provides a method of indicating own ship's course at various stations in the ship. It also provides own ship's course inputs to fire control systems, electronic systems, plotting equipment, and navigation equipment.

MASTER UNIT

The Mk 23 Mod 0 gyrocompass uses an electronic control system (fig. 14-4) to make it north-seeking. As discussed in *I. C. Electrician 3*, the controlling factors in making the compass north-seeking are the tilt of the gyro rotor, caused by the rotation of the earth, and the force of gravity. In this type of compass, however, the force of gravity, instead of acting directly to control the compass, merely acts on a special type of electrolytic bubble level (gravity reference) shown in figure 14-5, which generates a signal proportional to the tilt of a gyro axle. After amplification, this signal is used to apply torques electromagnetically about the vertical or horizontal axes to give the compass the desired period and damping.

The gyro is enclosed in a hermetically sealed sphere called a gyrosphere (figs. 14-6 and 7) and is suspended in oil. When the weight and buoyancy of the gyro are properly adjusted in the oil, no load is placed on the vertical pivots. This liquid suspension eliminates the effect of shifts of the center of mass of the sensitive element (north-seeking component) with respect to the suspension axis since the gyrosphere has no weight in oil. Liquid suspension also provides shock protection for the sensitive element and minimizes the effects of acceleration on the sensitive element since the center of gravity and center of buoyancy coincide. In addition to eliminating the load on the vertical pivots, the flotation in oil minimizes the load on the horizontal axis pivots. Only the weight of the vertical ring and its components. which are also reduced in weight because of partial flotation, load the bearings.

The compass is compensated for speed error. latitude error, mass unbalance, and supply voltage fluctuations. These compensations will be discussed later. In addition to the normal operating range of latitude, the compass incorporates controls which make it suitable for accurate operation at high latitudes (near the poles) as a directional gyro. The compass has an electronic followup system (fig. 14-8) which detects movements of the gyro through a pickoff. This device produced an electrical signal proportional to gyro movement from its null position. After amplification, the signal drives the followup motor to maintain alignment of the phantom and the vertical ring with the gyro rotor at all times. This system also provides smooth accurate transmission of 1- and 36-speed heading data.

Control Cabinet

The control cabinet (fig. 14-1) houses all the equipment required for operating and indicating the condition of the mastercompass except the compass failure annunciator and the alarm bell.

Speed Unit

The speed unit (fig. 14-1) contains the necessary components to produce an electrical signal proportional to speed. Speed data are received from the ship's underwater log equipment or are set in manually. Speed range of the unit is from 0 to 40 knots.

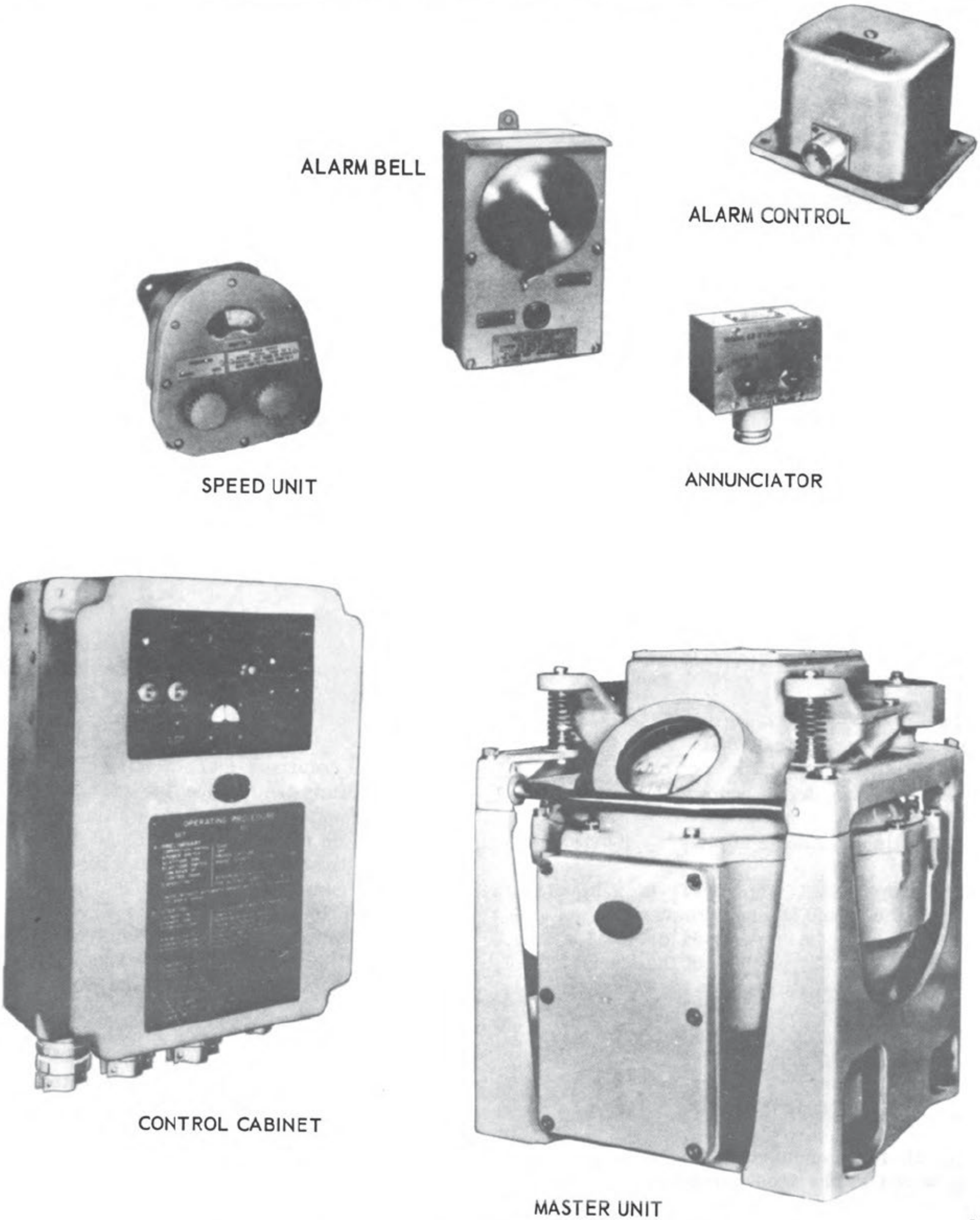

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Figure 14-1.—Sperry Mk 23 Mod 0 gyrocompass equipment.

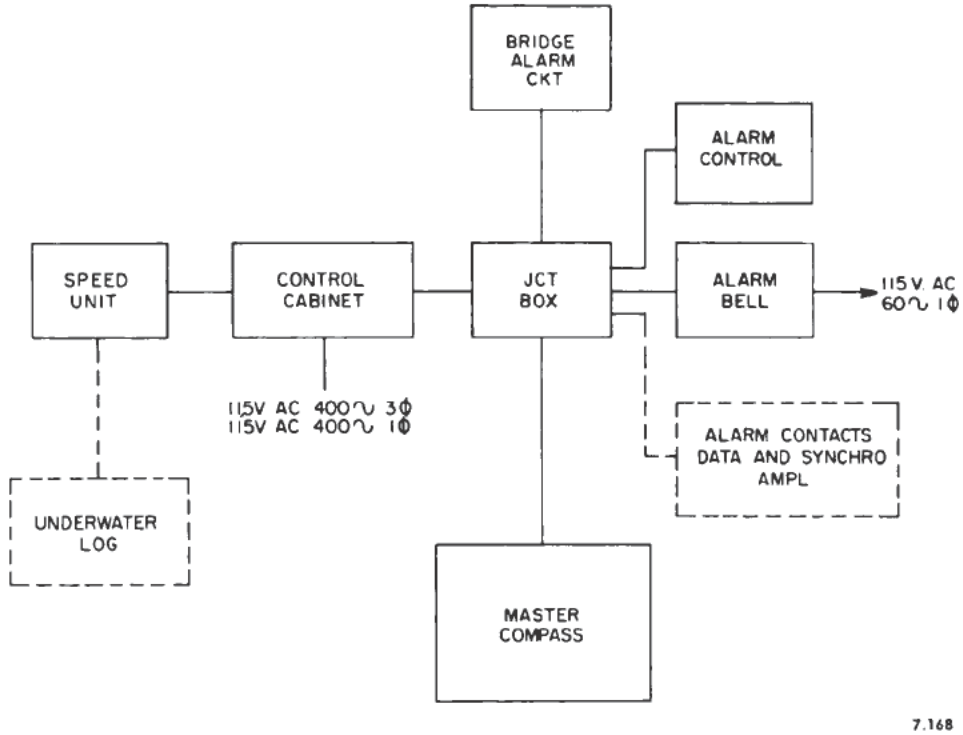

Figure 14-2.—Sperry Mk 23 Mod 0 gyrocompass system. Block diagram.

Alarm Control

The alarm control (fig. 14-1) contains the necessary relays and components to actuate an alarm (flashing light or bell) when certain portions of the system become inoperative.

Alarm Bells and Annunciators

The alarm bell (fig. 14-1) is a standard Navy B-10 bell and is most frequently used with this equipment. A type B-51 or B-52 alarm panel may be used in place of the annunciator. The alarms are actuated by the alarm control and ring when the system fails. Either the bell or the annunciator, or both, may be used to indicate system failure.

MASTER UNIT CONTROL SYSTEM

Recall for a moment what the weights that were added to the free gyroscope actually do. The weights were added so that the force of gravity could be used to precess the gyro and make it north-seeking. Also remember that the action of the weights depends upon the gyro axle tilting due to earth rate (rate of rotation of earth about its axes).

Now, if the effect of the unbalanced weights on the gyro could be produced without the weights, the effect of horizontal acceleration on the gyro would be minimized since the gyro would be balanced (nonpendulous). To eliminate the weights, some method must be found for measuring the tilt of the gyro axle caused by the earth rate since the effect of the weights is proportional to tilt. Then some way must be found to use this indication to control devices which would produce torques proportional to tilt about the vertical and horizontal axes.

GRAVITY REFERENCE SIGNAL

In this compass the tilt is detected by a gravity reference, attached to the vertical ring (fig. 14-9) so that it is parallel to the gyro axle. This device is a special electrolytic bubble level which transmits an electrical signal with magnitude and sense according to tilt. Since the electrolytic bubble level and axle are parallel and rigidly fixed with respect to each other, the signal emitted by the bubble level is

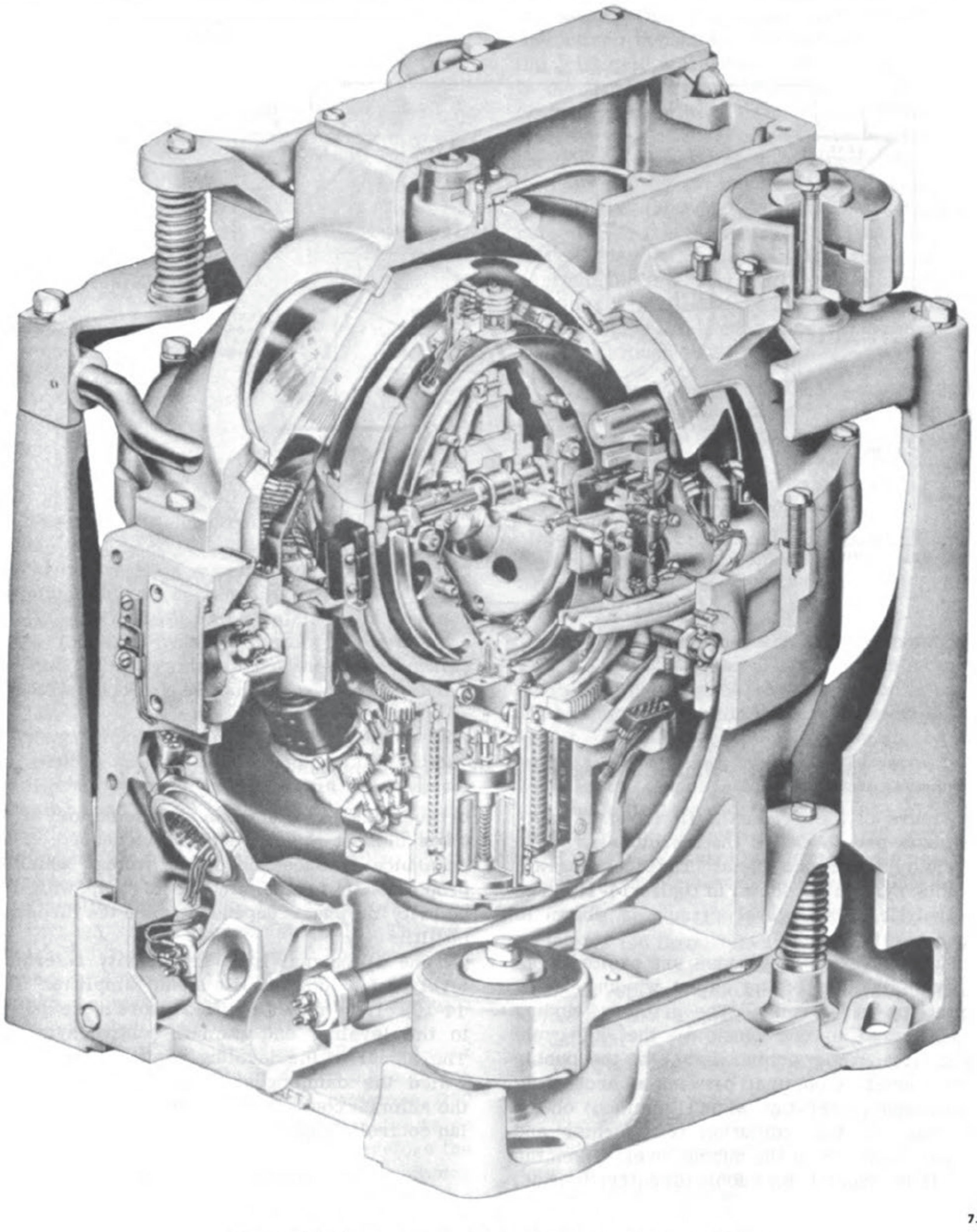

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Figure 14-3.—Cutaway view of master compass unit.

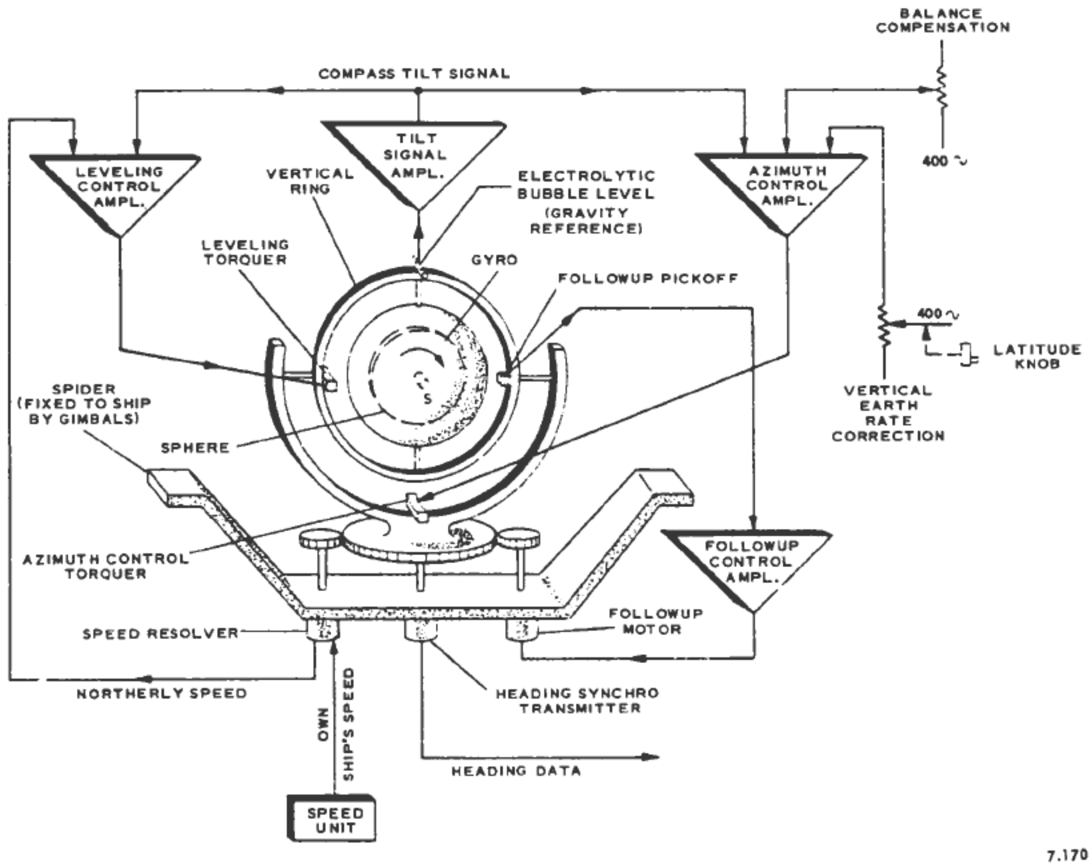

Figure 14-4.—Simplified diagram of Mk 23 gyrocompass with all controls.

a measure of the gyro axle tilt about the east-west axis and is called the meridian gyro tilt, or gravity, reference signal. The block diagram for this system is shown in figure 14-10. The electrolytic bubble level circuit is shown in figure 14-11.

The two lower electrodes are excited from the opposite ends of the output winding of the excitation transformer. The primary winding is connected to one phase of the 400-cycle power line. The output signal of the bubble level circuit is obtained between an accurately determined center-tap (signal common) on the secondary of the excitation transformer and the top electrode of the bubble level. When the level is horizontal, the bubble is centered. Thus, the resistance between the top electrode and either lower electrode is equal and the output signal is zero. When the level is not horizontal, the bubble is not centered and the resistance between the top electrode and the bottom electrode closest to the bubble is increased. This unbalance produces an output voltage which is proportional to the amount of tilt, with the polarity or phase dependent upon the direction of tilt.

The tilt signal from the gravity reference level is fed into the tilt signal amplifier (fig. 14-10). Here it is amplified before it is supplied to the leveling and azimuth control systems. The signal to the leveling control amplifier is called the damping signal. The signal fed to the azimuth control system is called the meridian control signal.

TILT SIGNAL AMPLIFIER

The tilt signal amplifier (figs. 14-10 and 14-13) is included in the control cabinet. The purpose of the amplifier is to amplify the tilt

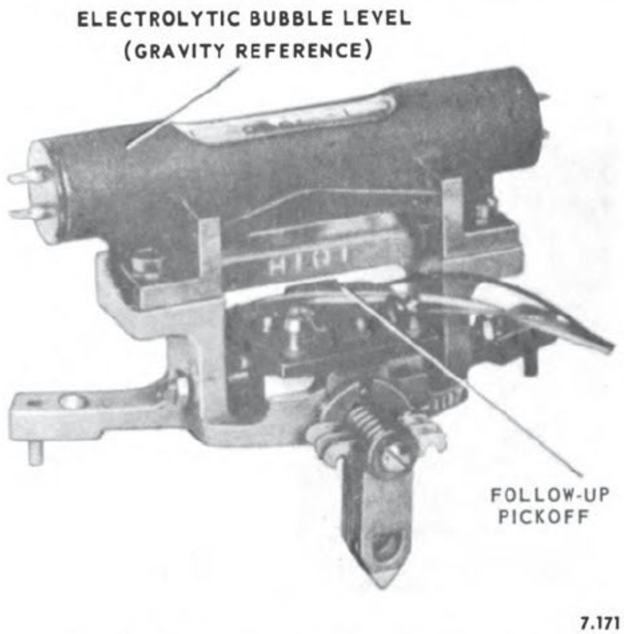

Figure 14-5.—Electrolytic bubble level.

signal before it is supplied to the leveling and azimuth control systems as shown in figure 14-12. The amplifier consists of a pentode stage followed by two cathode followers, one for the damping signal and the other for the meridian control signal, as shown in figure 14-13.

The compass has two compass periods with different percentages of damping (a 30 minute emergency settling period with 90 percent damping and a 90 minute normal compass period with 65 percent damping). The amplification of the tilt signal is altered to obtain these operating conditions.

The tilt signal is fed to the grid of pentode V3 through series grid resistor R15. The output of V3 is coupled directly to the grid of cathode follower V4B. Potentiometer R25, provides a method for adjusting the magnitude of the meridian control signal.

A portion of the output of V4B is fed back from the cathode through C6 to the common connection between plate load resistors R20 and R21 of V3. This feedback is of the same phase as the plate signal of V3. Therefore the feedback changes the potential at the common connection of R20 and R21 at the same time and in the same direction that the input signal changes the voltage at the plate end of R21. This potential change at both ends of the resistor is the same. Thus the voltage drop across R21 is maintained constant. This feature ensures that the V4B grid will remain negative with respect to the cathode and will not draw current. The changes in current show up only across R20 (the voltage drop across R21 is constant) with capacitor C6 supplying the current path.

Consider the circuit when the V3 grid signal is positive-going. This signal will cause the potential at the plate and at the junction of R20 and R21 to decrease by equal amounts. The current through R21 will remain constant as previously explained. However, the potential across C6 will increase causing an increase in current through R20.

When the V3 grid signal is negative-going, the reverse action takes place. Plate and junction (R20 and R21) voltages increase equally. R21 current again stays constant but potential across capacitor C6 decreases causing a decrease in current through R20.

The change in voltage at the plate end of R21 is also reduced by negative feedback to the screen grid through the voltage divider, R22 and R23, to ground.

The gain of the tilt amplifier, without negative feedback is about 2000. The gain needed for a 30-minute quick-settling period is 90 and the gain needed for the normal 90-minute period is 10. To obtain the required gain for both periods, another negative feedback loop is needed between the output of the cathode follower V4B, and the grid of the input tube V3. The circuit is from pin 8 of V4B, via C7, R24, R16, and C4 to pin 1 of V3. S4A shorts R24 in certain positions to control the amount of negative feedback.

The meridian control signal from the cathode of V4B is fed through switch S4B to the azimuth control amplifier. Potentiometer R25, is the cathode resistor and also provides a means of adjusting the amplitude of the signal. This adjustment is set at the factory and should not be readjusted unless the potentiometer is replaced.

The meridian signal obtained from the cathode of V4B is applied to the grid of V4A. Potentiometer R26 provides a means for adjusting the damping signal. The damping signal is fed through switch S4C, which connects the proper damping signal network for the mode of operation selected.

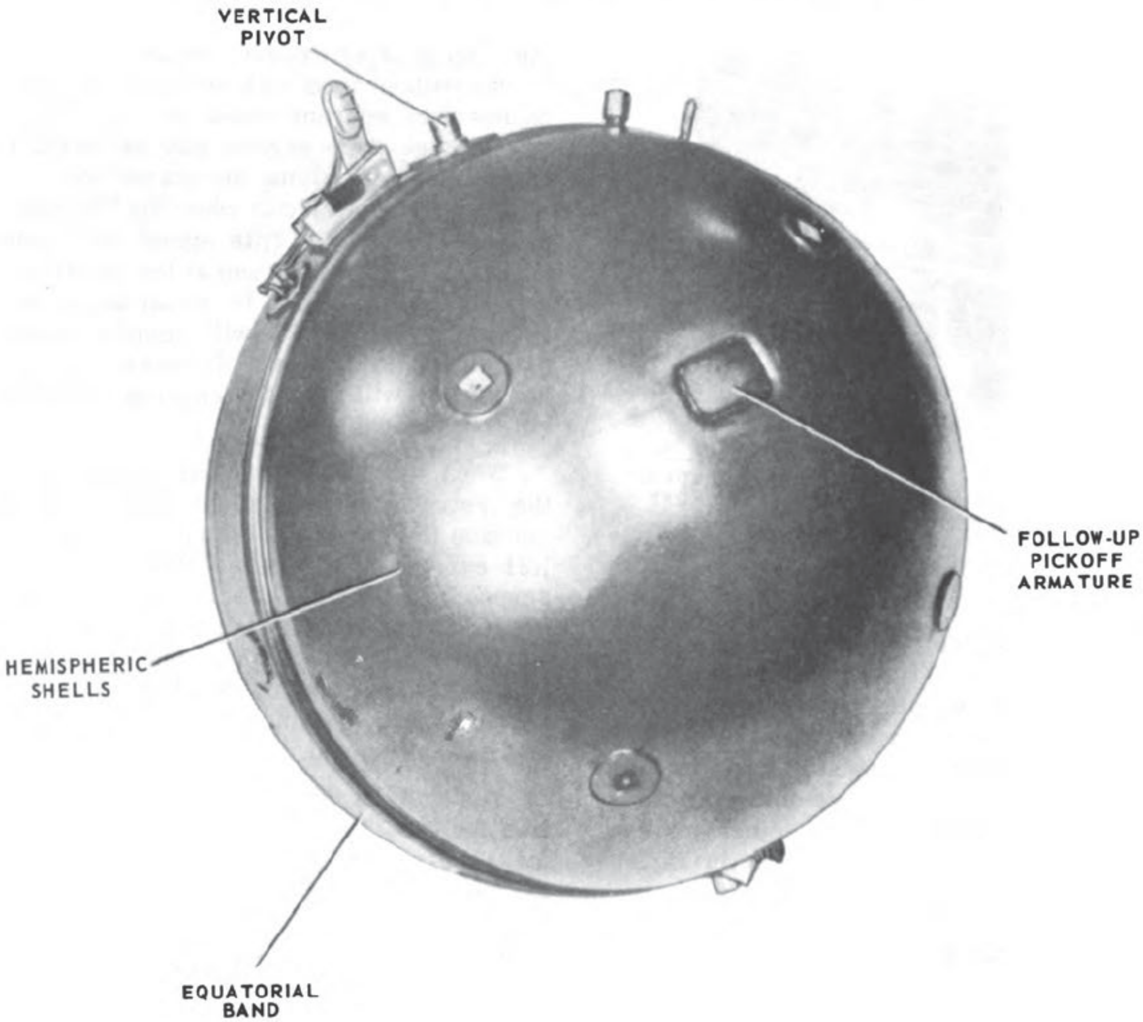

Figure 14-6.—Gyrosphere.

AZIMUTH CONTROL SYSTEM

The azimuth control system, shown in figures 14-12 and 14-14, consists of the azimuth control amplifier, azimuth control torquers (fig. 14-9), latitude switch, balance adjustment and vertical earth rate compensator. The azimuth control system produces a torque about the horizontal axis which causes precession of the gyro in azimuth. There are three input signals to the system: the meridian control, the latitude or vertical earth rate correction, and the balance correction signal. The meridian control signal is obtained from the gravity reference system. Latitude and balance data are entered into the system by manual adjustment. The output of the system is a torque about the horizontal axis of the gyro.

MERIDIAN CONTROL SIGNAL

The meridian control signal is fed into the azimuth control amplifier from the tilt signal amplifier, as shown in figure 14-13. This signal is the main control signal in the azimuth control system.

Latitude Switch

In order to obtain satisfactory compass periods in both high and low latitudes, a latitude switch S5 (fig. 14-13) is provided which gives

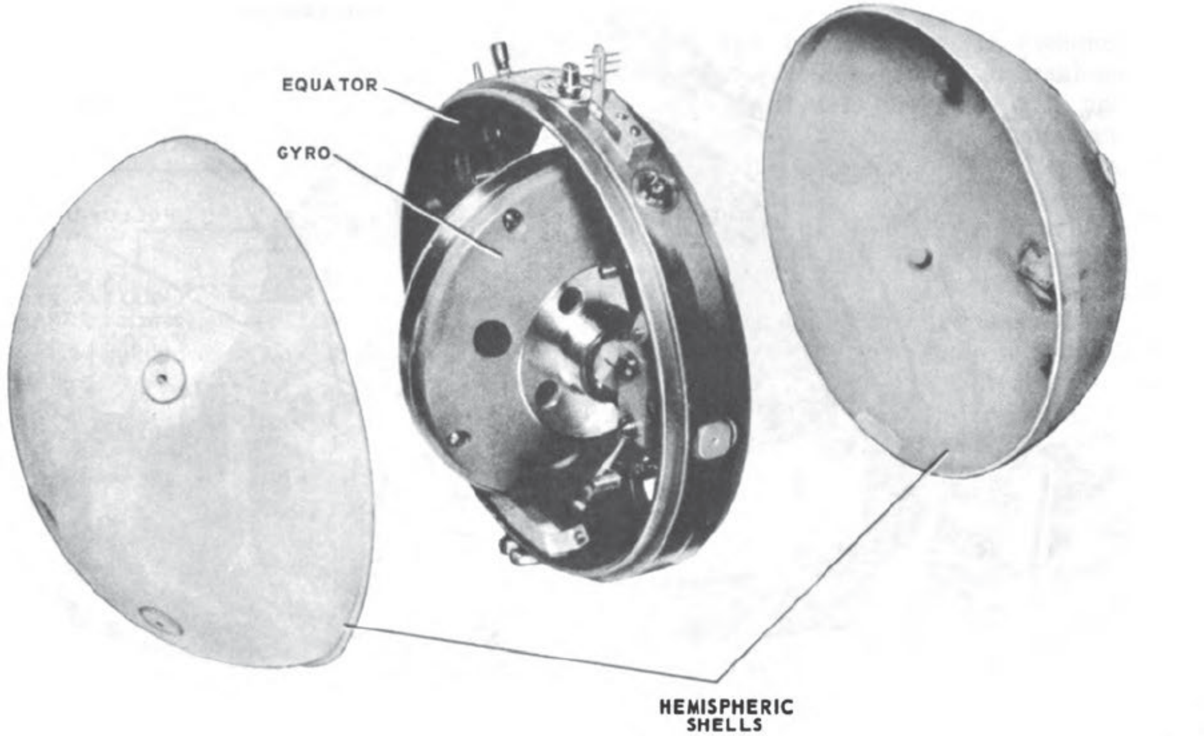

Figure 14-7.—Exploded view of gyrosphere.

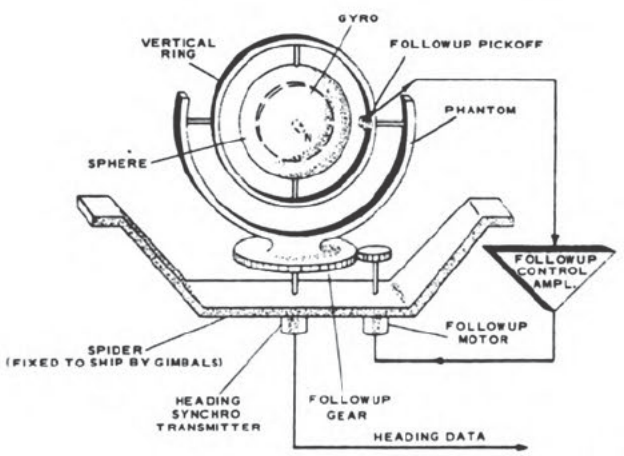

Figure 14-8.—Simplified diagram of followup controls on gyrocompass.

the compass a 90-minute period at either of two latitudes—45° or 65°. To give the compass the same period at both latitudes, a change in magnitude of the meridian control signal must be obtained. This change is accomplished by the latitude switch which alters the connection of the meridian control signal mixing resistors R43 and R44, located in the azimuth control amplifier channel of the control amplifier. In older type compasses the period is controlled in both high and low latitudes by varying the rotor speed.

Balance Adjustment

The balance adjustment, shown in figure 14-13, is provided as a convenience for shipboard operation. This adjustment permits the effects of mechanical imbalance in the master compass to be corrected without actually making the mechanical adjustments in the master gyrocompass. The balance adjustment provides an electrical signal to the azimuth control amplifier, putting torque on the gyro to compensate for any mechanical imbalance. The adjustment consists of the balance compensator potentiometer R30, and balance sense switch S6. The power for the balance adjustment is derived from the center-tapped secondary of transformer T4 located in the compensated voltage

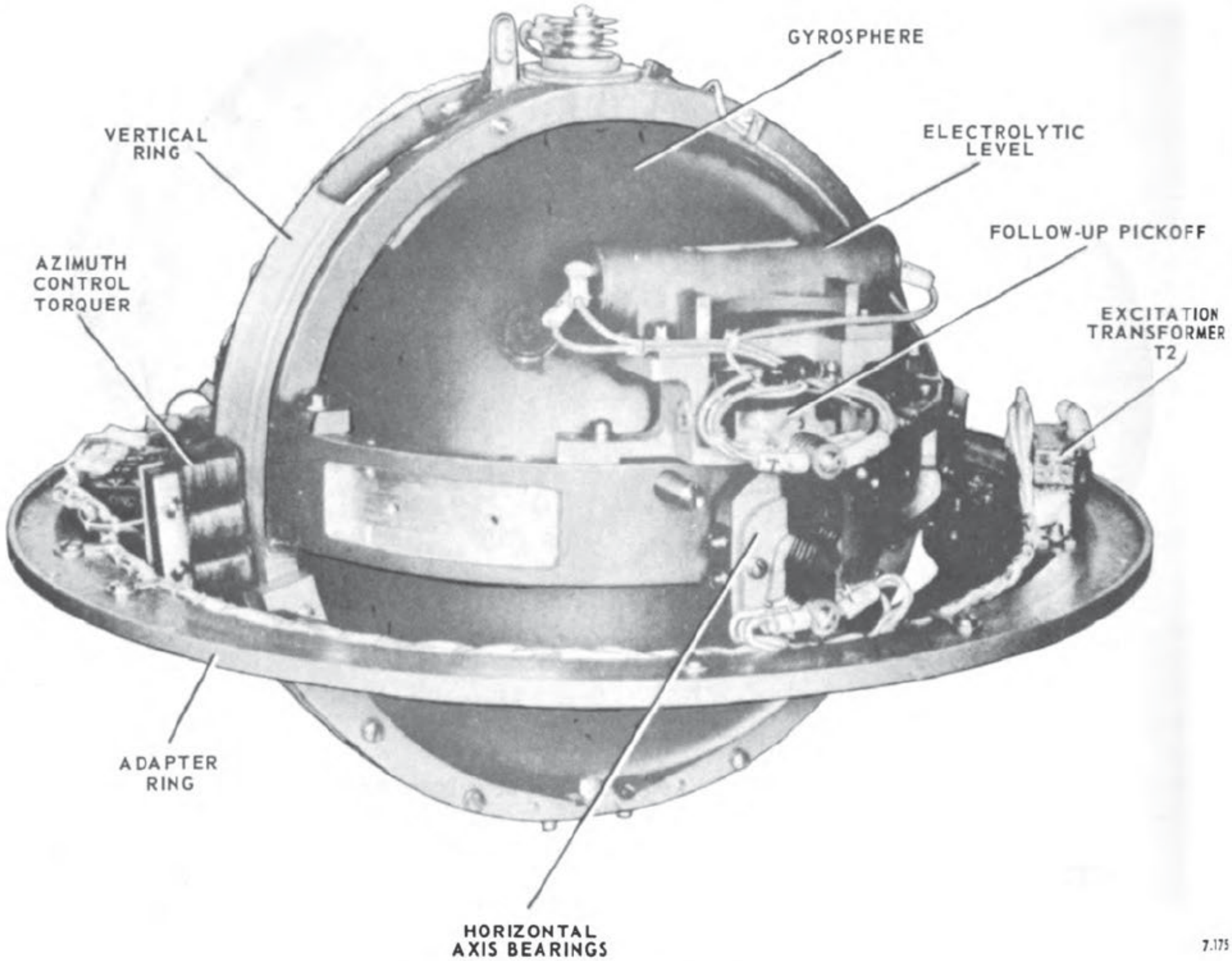

Figure 14-9.—Sensitive element.

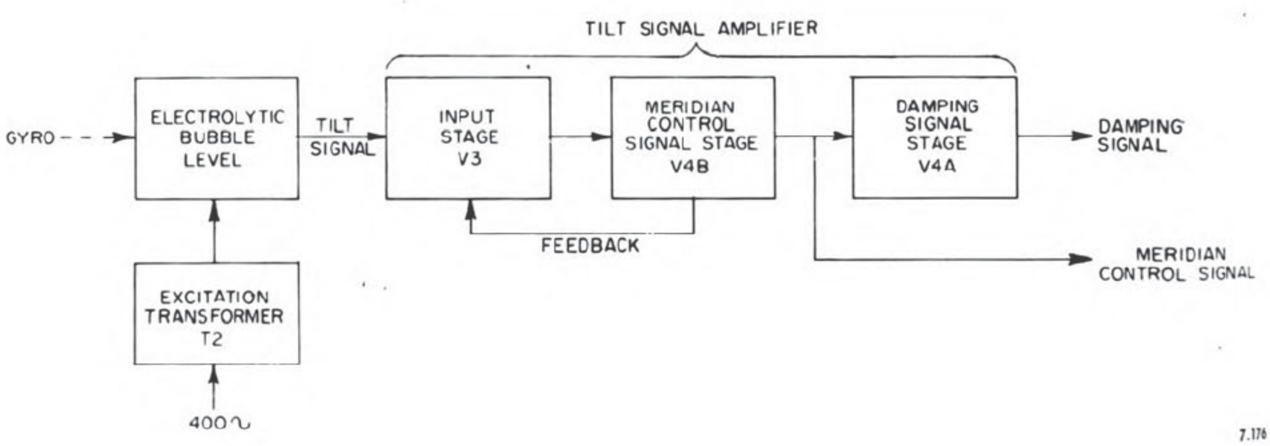

Figure 14-10.—Block diagram of gravity reference system.

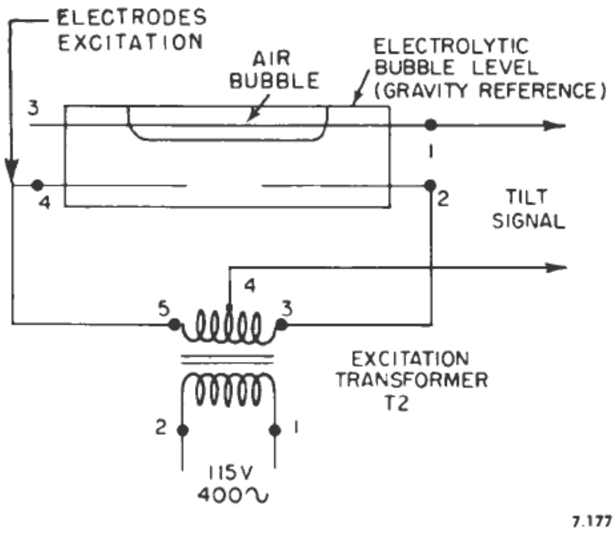

Figure 14-11.—Schematic diagram of electrolytic bubble level.

supply. The center-tap is at the signal common potential (ground).

The other two leads from the transformer are connected to the 3-position balance sense switch S6. This switch enables adjustment to compensate for a north or south high end condition. Potentiometer R30 is used to adjust the magnitude of the balance correction.

Vertical Earth Rate Compensator

If a free running gyro is assumed to be mounted at either the north or south pole with its axle horizontal, the gyro will appear to rotate about its vertical axis at the rate of one revolution in 24 hours. This effect is called vertical earth rate. It varies as the sine of the latitude and is equal to the angular velocity of the earth itself at the poles, and is zero at the equator.

A vertical earth rate compensation circuit (fig. 14-13 and 14-14) makes a correction for vertical earth rate by feeding a latitude input signal into the azimuth control amplifier. The signal is manually cranked in by the latitude control on the control panel. The circuit consists of resolver CT2, resistor R34, and capacitor C10.

The rotor of the resolver, CT2, is connected to provide a variable output voltage excited from the secondary of transformer, T4, located in the compensated voltage supply. The output voltage of CT2 is the product of the excitation voltage and the sine of the angle of the latitude control shaft displacement. This voltage therefore is proportional to the local vertical earth rate. Potentiometer, R33, across the output of the resolver is used to adjust and calibrate the

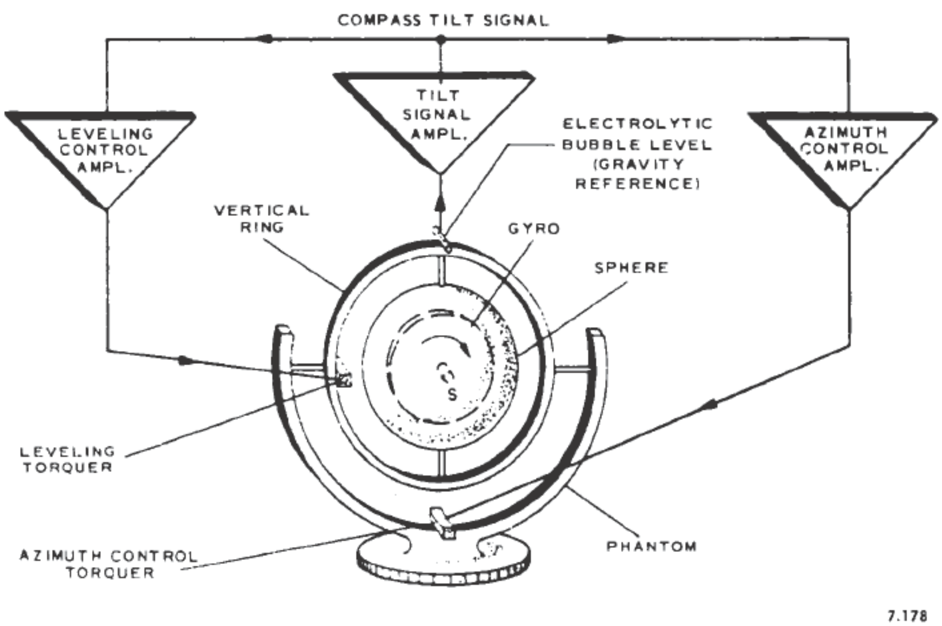

Figure 14-12.—Simplified diagram of electrical azimuth and leveling controls.

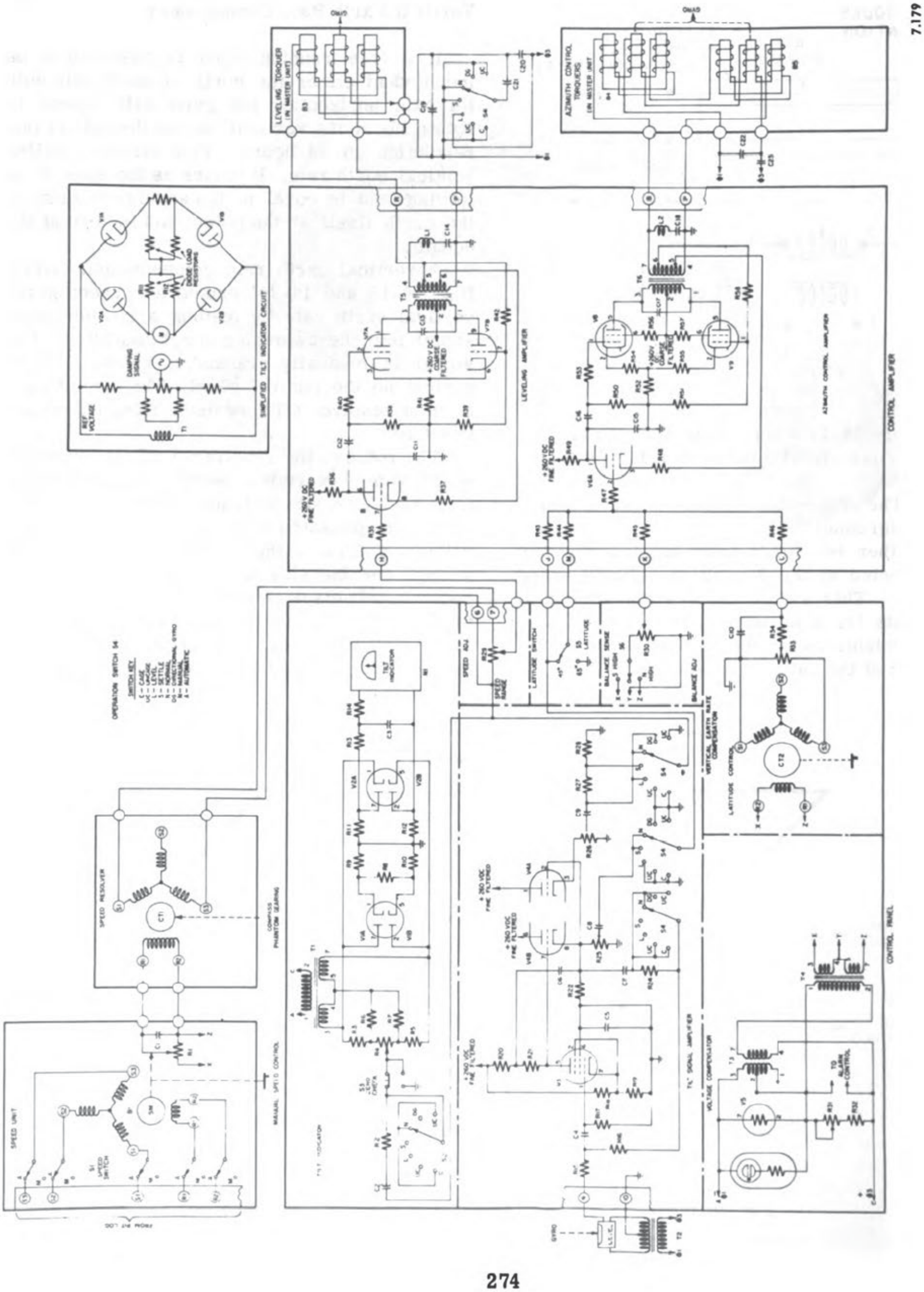

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Figure 14-13.—Simplified schematic of all compass controls.

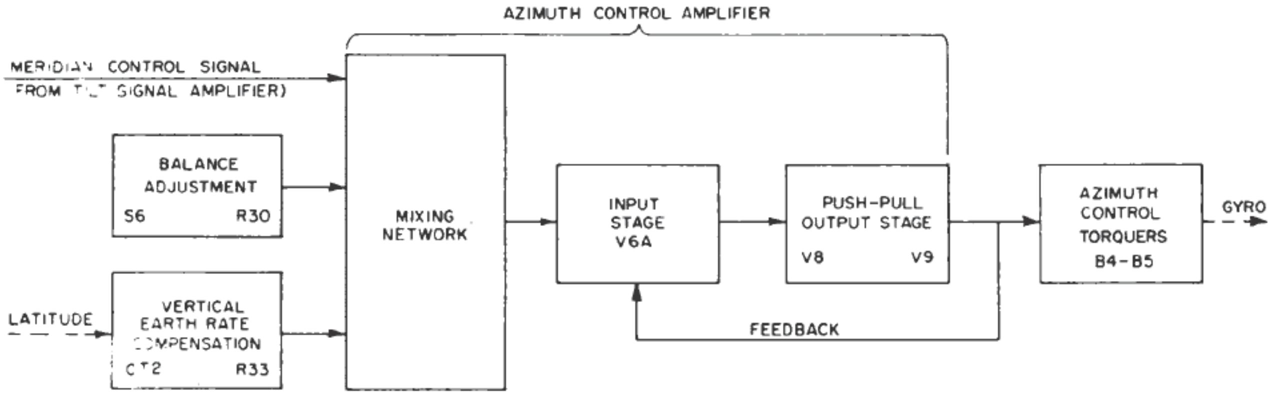

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Figure 14-14.—Block diagram of azimuth control system.

vertical earth rate signal. Series resistor, R34, and shunt capacitor, C10, compensate for the phase shift in the synchro.

Azimuth Control Amplifier

The azimuth control amplifier is a part of the control cabinet. It mixes three input signals, amplifies the combined signal, and feeds the control fields of the azimuth control torquers (fig. 14-13). The amplifier consists of a triode input stage driving a push-pull output stage as shown in figure 14-13.

Three signal voltages are fed into the amplifier through mixing resistors. These signal voltages as previously mentioned are: meridian control signal (voltage proportional to gyro tilt), balance adjustment signal, and vertical earth rate compensation signal.

These three signal voltages are fed to the grid of V6A. Capacitor C15, connected from the plate of V6A to ground, limits the high frequency response of the amplifier and provides increased stability.

The output stage consists of two pentodes connected in push-pull. The grid of output tube V8 is excited from the output of V6A. The grid of output tube V9 is excited from the secondary of output transformer T6. Output transformer T6 is used to match the impedance of the output stage to the tuned impedance of the series connected control fields of the azimuth control torquers.

Capacitor C18, in series with L2, across the secondary of T6, corrects the power factor of the torquer load, and the inductor alters the frequency characteristic of the amplifier and ensures stability. A negative feedback voltage is taken from a tap on the secondary of the output transformer and is fed back to the cathode of the input stage. This feedback keeps the overall voltage gain of the amplifier to 2, and the maximum output power to 5.5 watts.

Azimuth Control Torquers

The azimuth control torquers (fig. 14-9) are the output elements of the azimuth control system which actually produce the torques applied to the gyro. The torquers are located diametrically opposite each other on the adapter ring and are electrically connected to act together to produce the torque.

Each torquer consists of an open-E rack structure of soft-iron laminations, upon which are wound a control field (2 outer legs) and a reference field displaced 90 degrees to form a 2-phase induction motor field. These coils are excited from the output of the azimuth control amplifier.

The output voltage of the amplifier and the reference field voltage are 90 electrical degrees out-of-phase. When the torquer windings are energized, a moving field is set up in the air gap. This field cuts the vertical ring and induces currents in it. This action develops a torque that tends to drag the vertical ring along with the moving field.

The magnitude of the torque is proportional to the signal fed to the control winding (output of the amplifier). The direction of the torque depends upon the phasing of the control-field voltage which may lead or lag the fixed-field voltage by 90 electrical degrees. To obtain the correct phase relationship between the control

and fixed fields, two capacitors, C22 and C23, shift the phase of the reference field.

LEVELING CONTROL SYSTEM

The leveling control system (fig. 14-15) consists of the leveling amplifier, leveling torquer, and speed corrector. The only electrical signal inputs to the system are the damping signal from the tilt signal amplifier and the speed signal from the speed corrector. The output of the system is a torque about the vertical axis which precesses the gyro to a level position.

LEVELING AMPLIFIER

The leveling amplifier (fig. 14-15) is part of the leveling control system. Its purpose is to amplify the combined series-mixed damping and speed correction signals. The output of the amplifier is connected to the control field of the leveling torquer.

The leveling amplifier is very similar to the azimuth control amplifier. The combined signal is fed to the grid of the input state V6B, as shown in figure 14-13.

The output stage consists of the dual triode V7A and B. Output tube section V7A is excited from the output of tube V6B. The grid of tube section V7B is excited from the secondary of output transformer T5.

The use of part of the output from the transformer to excite tube V7B produces the proper phase inversion necessary for push-pull operation. The output transformer T5 is used in matching the output stage to the tuned impedance of the leveling torquer control field.

Power factor correction and frequency characteristic alteration are accomplished by a capacitor and an inductor across the secondary of the output transformer T5. A portion of the output is fed back as negative feedback to the input stage. The magnitude of the feedback limits the amplifier voltage gain to 1.

LEVELING TORQUER

The leveling torquer (fig. 14-16) is the output element that actually produces the torque which precesses the gyro about the vertical axis to a level position. The torquer, located on the horizontal part of the vertical ring, is identical to the azimuth control torquers and operates in the same manner. However, there is only one leveling torquer. For detailed discussion of the principle of operation refer to the discussion of azimuth control torquers previously mentioned.

In the leveling control torquer, the reference field is excited from phase 1-3 of the 400-cycle supply, as shown in figure 14-13. During certain modes of operation, it is necessary to increase the reference-field voltage and shift it 90 degrees in relation to the control-field voltage. This is accomplished by connecting the capacitors as shown in figure 14-13.

TILT INDICATOR

The tilt indicator meter supplies a visual indication of the tilt of the gyro axle during

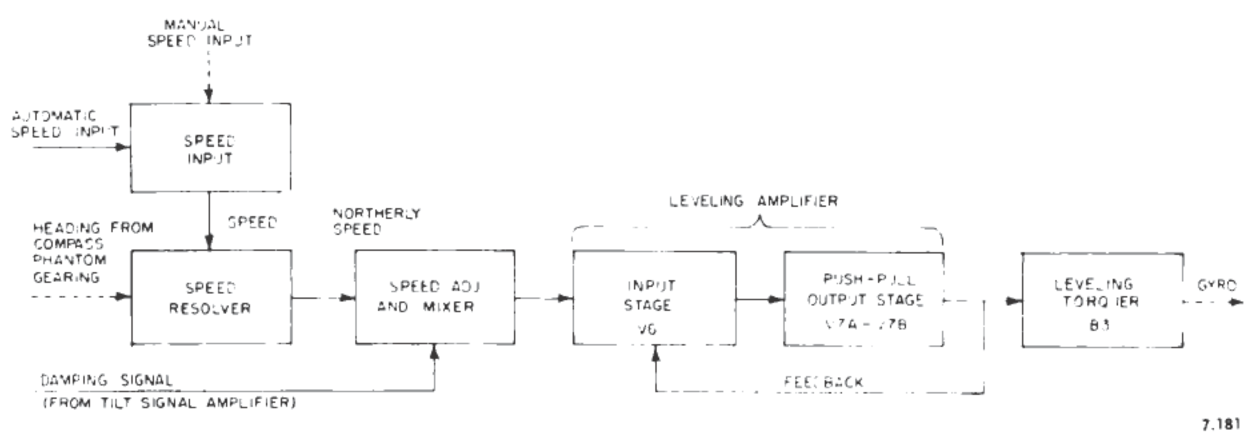

Figure 14-15.—Block diagram of leveling control system.

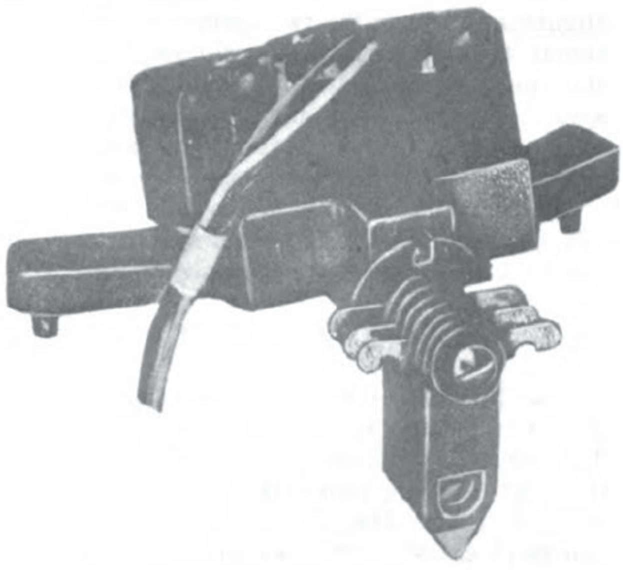

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Figure 14-16.—Leveling torquer.

starting and operation. To detect the direction of the tilt a phase sensitive demodulator circuit is used (fig. 14-13).

The tilt indicator circuit is a full wave diode phase sensitive demodulator. The circuit may be considered to be composed of two half wave sections. The reference transformer T1, together with a resistor network is used for both half wave sections.

The output of the cathode follower V4A in the tilt signal amplifier (fig. 14-13) is the damping signal for the tilt meter circuit. It is applied effectively between the center-tap of the diode load resistors and the center-tap of the reference voltage transformer through a balance potentiometer. The signal is either in-phase or 180 degrees out-of-phase with the reference voltage.

If the input signal is zero, the output voltage of the demodulator section will also be zero. If an input signal adds to the a-c reference voltage applied to V2A, it will subtract from the a-c reference voltage applied to V2B. This means tube section V2A will conduct more current. The voltage drop across the meter on one half cycle will be greater than that on the next half cycle and the net d-c output voltage will be proportional to the a-c signal voltage. If the phase of the signal voltage is reversed, the polarity of the d-c output voltage will reverse. The two half-wave sections are V1A and V2B, and V2A and V1B.

VOLTAGE COMPENSATOR

Two methods of compensating for the effect of line voltage variations in the torquer circuits are possible. The first method is to regulate the voltage to the reference field and to regulate the excitation voltages for the signal sources. This, however, is undesirable as it would require a large voltage regulator. The second and more desirable method which is used in this equipment is to leave the reference fields of the torquers unregulated but to compensate the excitation voltages of the signal sources. This compensation is such that the excitation voltages are changed by the percentage of any power line change but in an opposite sense; if the power line voltage drops, the excitation voltage rises. The net result is that the torque produced by the torquer is constant. The voltage compensating circuit supplies excitation voltage for vertical earth rate correction, speed correction, and balance correction.

The voltage compensator circuit is shown in figure 14-17. The a-c line voltage is impressed across the series circuit consisting of resistors R31 and R32 and ballast current regulating tube V5. Because of the constant current design of the tube, the voltage across the series resistors remains constant. The voltage change across V5 is the same as the voltage change of the power line.

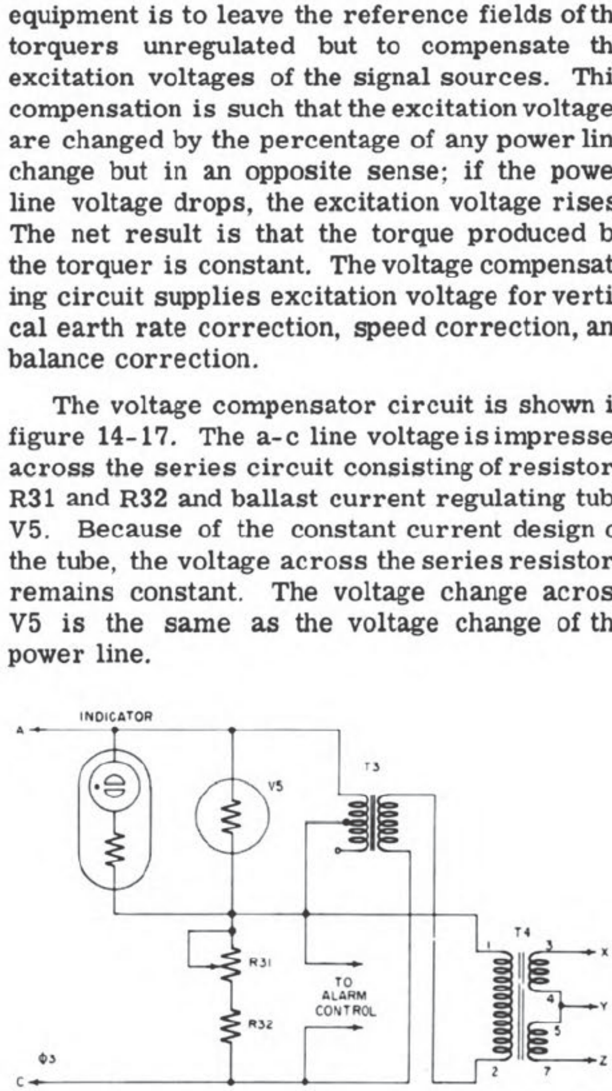

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Figure 14-17.—Simplified schematic of voltage compensator circuit.

The voltage across the ballast tube is impressed on the primary of the stepdown transformer T3. The stepped-down voltage across the secondary of transformer T3 is subtracted from the constant voltage drop across the series resistors and the difference is impressed on the primary of the excitation transformer T4. The output from the secondary of transformer T4 is fed to the various correction circuits.

If the line voltage drops, the voltage across V5, and therefore, the voltages across the primary and secondary of T3 must drop. However, the voltage across R31 and R32 would remain the same. This means the sum of the voltage drops across the secondary of T3 and the primary of T4 must equal that across the resistors. In order to do this, the voltage across T4 (primary) must increase when that across T3 (secondary) decreases if the IR drop across the resistors remains constant.

A simplified schematic of all compass controls is shown in figure 14-13.

FOLLOWUP SYSTEM

The purpose of the followup system, shown in block diagram figure 14-18, is to drive the phantom bowl in azimuth, keeping the vertical ring and the plane of the gyro wheel in continuous alignment. The synchro data transmitters and speed resolver are also positioned by this alignment. The system is a closed-loop servo in which a pickoff device between the vertical ring and gyrosphere provides an error signal. This signal is proportional to the misalignment between the two elements. The error signal is amplified by the followup amplifier and operates the followup motor located on the spider. The followup motor drives the phantom, and therefore the vertical ring in azimuth, to reduce the error signal to zero.

The system consists of the followup pickoff, followup amplifier, followup motor, followup alarm, and manual azimuth controls.

FOLLOWUP PICKOFF

The followup pickoff T7 shown in figure 14-19, is a small transformer with an E-shaped core. The core is mounted on a horizontal portion of the vertical ring immediately under the electrolytic level. The E is closed by a ferramic armature cemented on the gyrosphere. When the gyrosphere and vertical ring are aligned, there is no unbalance of the magnetic circuit through the transformer legs. But when the phantom and vertical ring are moved to the left, for instance, the E-shaped core moves with it. However, the armature remains fixed because of the rigidity of the gyro. As a result, the neutral position of the core and armature is upset and the magnetic field is stronger in the right coil. This causes an increase in the amplitude of the voltage induced in the right coil while that induced in the left coil is less. The resulting voltage output is the sum of the two voltages induced in the secondaries. The phase of the output voltage is the same as the phase of the greater voltage. By using the phase of the input voltage as a reference, the phase of the signal establishes whether the core was

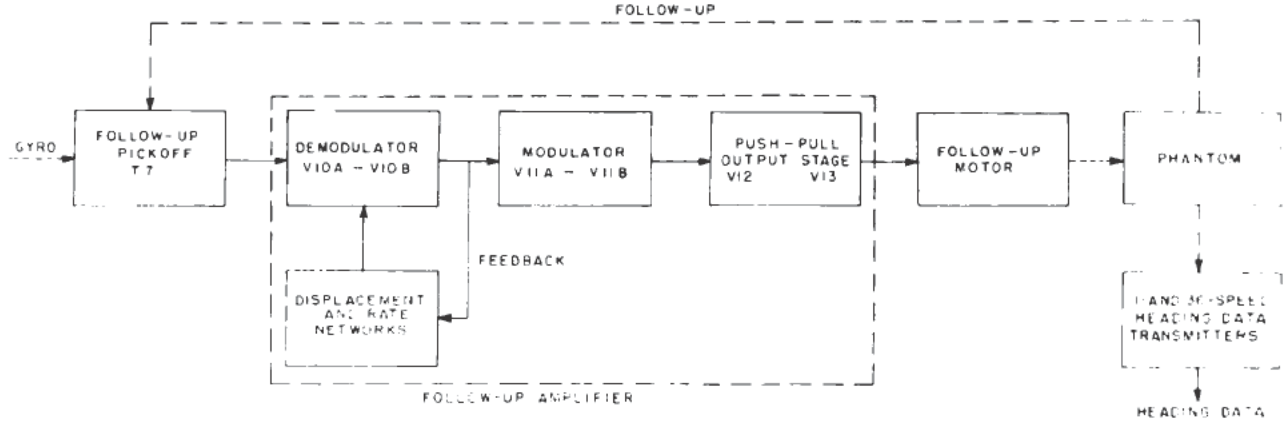

Figure 14-18.—Block diagram of compass followup system.

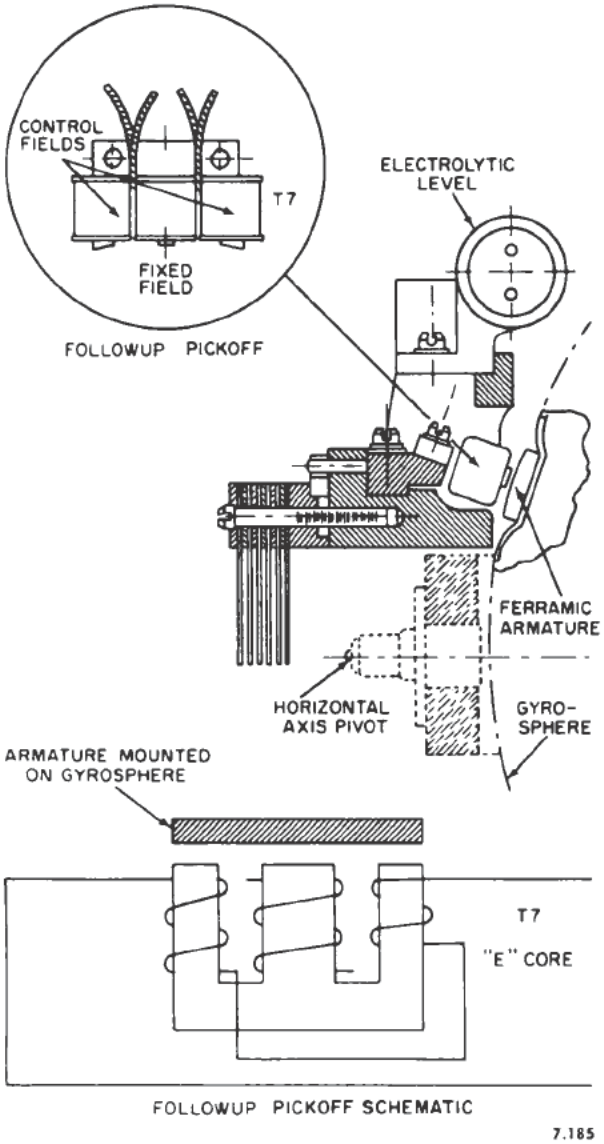

Figure 14-19.—Followup pickoff.

moved to the right or left. It also indicates the direction in which the phantom and vertical ring must be driven to maintain alignment of the vertical ring and gyrosphere.

FOLLOWUP AMPLIFIER

The followup amplifier is located in the control cabinet. The amplifier is employed to provide the required voltage and power amplification to the followup pickoff signal. This amplified signal operates the followup motor which aligns the azimuth position of the phantom element and vertical ring with the azimuth position of the gyrosphere. The amplifier also provides the required stabilization for the followup system.

The followup amplifier, shown schematically in figure 14-20, is composed of a half-wave phase-sensitive demodulator input stage V10A and B. In this stage the 400-cycle a-c followup error signal is converted to a d-c voltage, across R71 and R72, proportional to the error signal whose polarity reverses when the sense (or phase) of the error signal reverses. A negative feedback signal, across R73 and R74, required for the stabilization of the control loop is generated from this d-c voltage. The d-c error signal together with the stabilization signal is applied to the input of a half wave modulator stage V11A and B. The output of this stage is a 400-cycle a-c voltage proportional to the combined signal input whose phase reverses as the polarity of its d-c input voltages reverse. The a-c output of the modulator is amplified in an output stage, V12 and V13, which supplies power to the control field of the 400-cycle followup motor.

DEMODULATOR STAGE

The followup pickoff signal is fed into the primary of input transformer T8 and is stepped up by a ratio of 1:10. The secondaries feed the amplified signal to the grids of the twin-triode demodulator tube sections, V10A and B. Each tube receives the same magnitude signal but opposite in phase. The series grid resistors R60 and R63 prevent loading of the input transformer and provide tube protection on positive grid excursions. The plates of the demodulator tubes are excited with a 400-cycle voltage obtained from the plate reference transformer T9. This voltage is phase-locked with the excitation voltage of the followup pickoff. The error signal voltage thus is either in-phase, or 180 degrees out-of-phase, with the voltage applied to the plates of the demodulator tubes, depending upon the sense of the error. Also the voltages on the plates of V10A and B are phased so that they are both positive or negative at the same time. Since the current flows through the tube only during the positive plate excursion, the output of each tube section is a half wave rectified current. The magnitude of current conducted by each

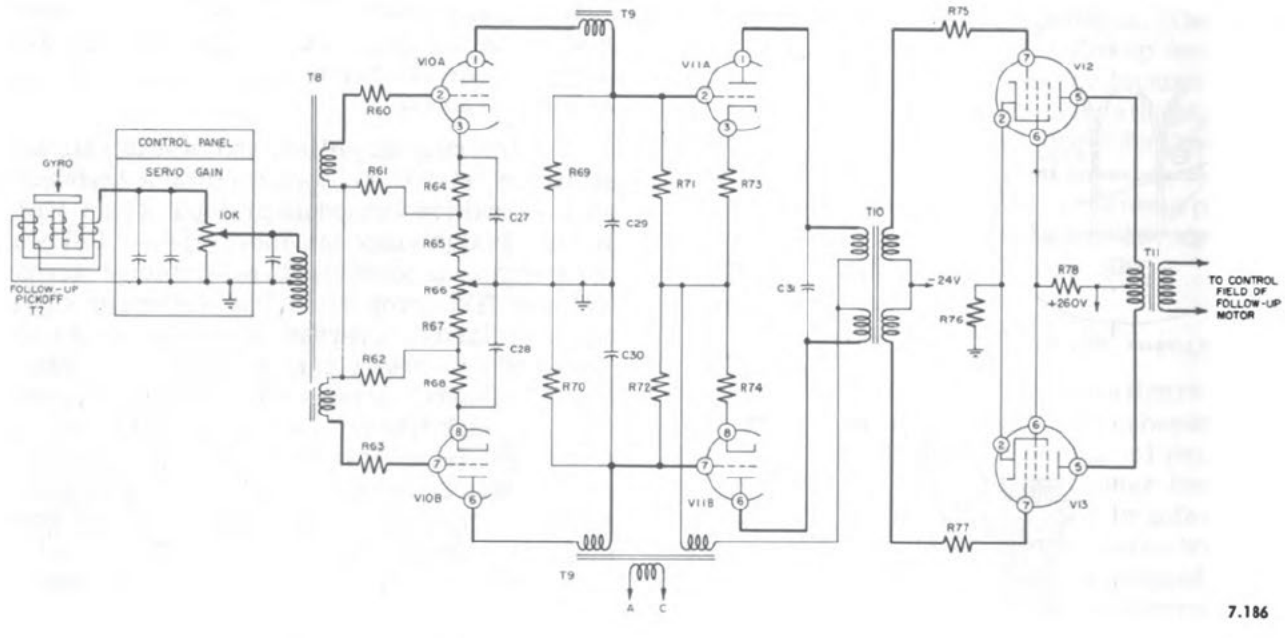

Figure 14-20.—Simplified schematic of followup amplifier.

half tube depends upon the instantaneous polarity of the grid and plate voltages of each section.

RATE NETWORK

A network in the feedback loop serves to produce a signal proportional to the rate of change of the error signal for momentarily increasing the demodulator gain. This network, called a rate circuit, enables a servo to overcome the effect of inertia in the moving parts of the compass followup system. The effect of this rate signal is to prevent a large momentary displacement between the pickoff and the gyrosphere.

COMBINED NETWORK

For most effective servo control, it is necessary to combine displacement and rate signals. Two circuits combining these signals are used in the demodulator stage of the followup amplifier. When these circuits are used together, it is not accurate to say that a particular component performs a certain function since the action is interrelated, therefore, the component will not be named but only listed. Referring to figure 14-20, the feedback loop network for tube V10A consists of C27, R61, R64, R65, and part of potentiometer R66; the feedback loop for tube V10B consists of C28, R62, R68, R67, and part of potentiometer R66.

MODULATOR STAGE

The d-c output voltage of the demodulator stage is applied to the grids of the half wave modulator tube sections V11A and V11B (see fig. 14-20). The plates of each half of the tube are connected to opposite ends of the center-tapped primary winding of modulator transformer T10. The center-tap of this winding is connected to the 400-cycle reference voltage obtained from one winding of the plate reference transformer T9. This reference voltage is phase-locked with the fixed-field excitation of the followup pickoff. Since the plates are excited through the center-tap of modulator transformer T10, the two sections conduct at the same time during their positive voltage excursions. If the input voltage is zero, V11A and B conduct the same amount of current. The current from V11A through the primary of T10 is equal but opposite to that from V11B. The net flux and the modulator transformer secondary voltage are zero.

When the demodulator d-c output is such that V11A conducts more than V11B, the net flux of the output transformer will have the same direction as the flux produced by the V11A plate current and the voltage induced in the transformer secondary will be of the same phase as the reference voltage.

The output voltage of the modulator is applied to the grids of the push-pull power output tubes V12 and V13. Transformer T11 is the output transformer and matches the plate impedance of output tubes V12 and V13, to the tuned impedance of the followup motor.

All plate voltages, the bias voltage for the output stage, and the filament voltages are obtained from the d-c power supply in the control cabinet.

FOLLOWUP MOTOR

The followup motor is mounted on the spider and is geared to the azimuth gear on the phantom. It is a 2-phase 4-pole induction motor having one of its stator windings (fixed-field) connected to one phase through a capacitance network. This network gives the proper phase shift for the 90 electrical degrees relationship between the control and fixed-field voltages. The direction of rotation depends upon the instantaneous polarity of the signal from the amplifier with respect to those of the fixed-field, and the speed of rotation depends upon the amount of displacement between the fixed and control fields.

POWER SUPPLY

The gyrocompass has 3 different power requirements. Power may be supplied from 3 different sources or converted from a single source. The primary power source is the 115-volt 400-cycle 3-phase supply which furnishes power for the entire unit with the exception of the heading data synchros. These synchros receive power from a 115-volt 400-cycle single-phase supply. The heaters in the binnacle receive power from a separate 115-volt 400- or 60-cycle single-phase supply. D-c power required for operation of the electronic circuits is supplied by a d-c power unit which operates from one phase of the 115-volt 400-cycle 3-phase supply.

ALARM SYSTEM

To provide a remote alarm indicator, an alarm control unit is installed. This unit receives an alarm signal and actuates an alarm indicator when failure occurs in the followup failure indicator circuit, the voltage compensator circuit, or the synchro amplifier. It also indicates main power failure.

COMPASS OPERATION

The starting procedure for the compass is given on the instruction plate on the face of the control and amplifier unit. Normally, preparations should begin at least 2 hours before the master gyrocompass is required for service. Further operating procedures may be obtained from the equipment technical manual.

CORRECTIVE MAINTENANCE

The first step in troubleshooting is to sectionalize the fault, and the second step is to localize the fault within the section.

Do not attempt to adjust or repair a component until the fault has been definitely located. Repair the fault and then completely check the equipment again to be sure no more than one fault existed.

When taking voltage measurements on any portion of the compass system, it is important to have the proper type of instrument. Selection of the instrument depends primarily on the impedance of the circuit concerned.

To determine if a system is functioning properly, it may be necessary to determine the relative phase relationship as well as the voltage magnitude of a circuit. Relative phase is important since the torque produced by a torquer, for instance, is not only dependent upon the voltage magnitude but also upon the phase angle between the control and fixed-field voltages. Usually the angle between the voltages is about 90 electrical degrees. In the Mark 23 gyrocompass system, the phase sensitive voltage measurements primarily involve the comparison of two a-c voltages whose frequencies are the same and whose phase differences should be 90 electrical degrees.

PHASING OF COMPASS SYSTEM

The simplest setup for measuring phase differences includes an oscilloscope and a

calibrated control transformer used as a synchro phase shifter, as shown in figure 14-21. The reference voltage is applied to the oscilloscope horizontal input through the synchro phase shifter. This may be the fixed-field voltage of the servomotor or torquer or any one of the power line phases. The voltage of the phase to be measured is applied to the vertical input of the oscilloscope.

To best use the synchro phase shifter, mount it on a small panel with a suitable 360-degree dial and an index. The first step is the calibration on the phase shifter. The calibration setup is shown in figure 14-22. However, as a preliminary before calibrating the phase shifter, the phase shift in the oscilloscope amplifiers must be determined. This is accomplished by connecting the input terminal of the oscilloscope vertical amplifier to the input terminal of the horizontal amplifier which is already connected to the phase shifter output. A straight slanted line as shown at A or C in figure 14-23 should be obtained. The direction of the slope of this line indicates the pattern for in-phase voltages and should be noted.

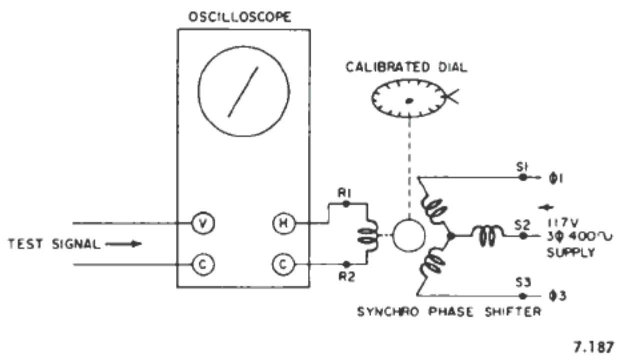

Figure 14-21.—Phase measurement equipment using a synchro phase shifter.

Now the calibration of the phase shifter can be made by connecting the vertical input to the output of the isolation transformer (point 3) which is connected to power line voltage phase 1-2 as shown. Recall from *Basic Electricity*, NavPers 10086-A, that when a 3-phase voltage is applied to a 3-phase stator winding (like that of the phase shifter under calibration), a rotating magnetic field is established around the stator. This field cuts the single winding of the phase shifter rotor and induces an a-c voltage in it, the phase of which depends upon the position of the rotor. Therefore, by rotating the shaft of the synchro phase shifter, until a straight line having the same slope as that previously determined may be obtained on the oscilloscope. Now, zero the synchro phase shifter by either moving the index or card, or by rotating the synchro housing until the dial reads zero when the in-phase pattern is obtained.

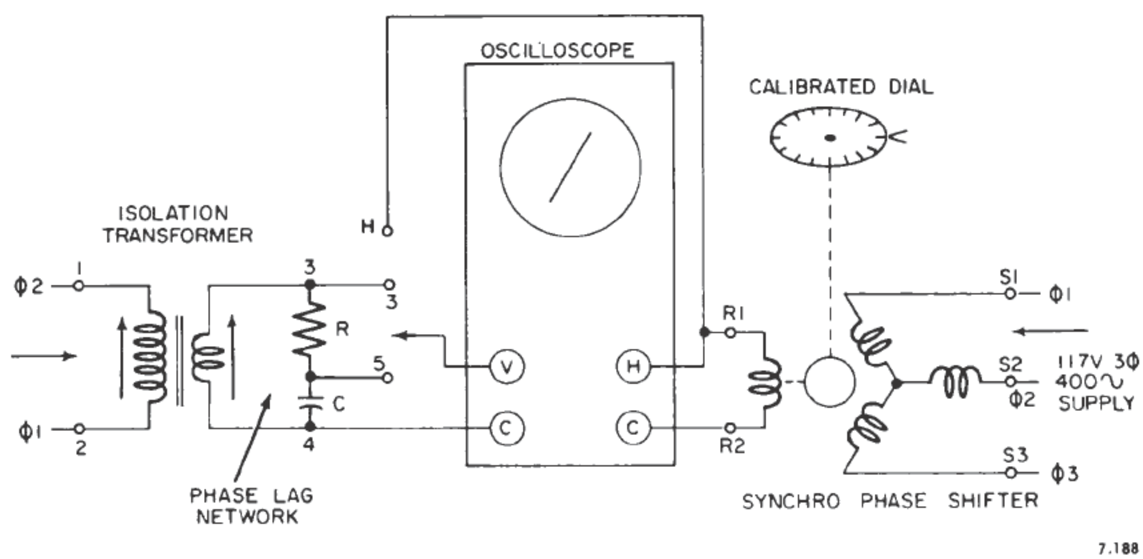

Figure 14-22.—Calibration of the synchro phase shifter.

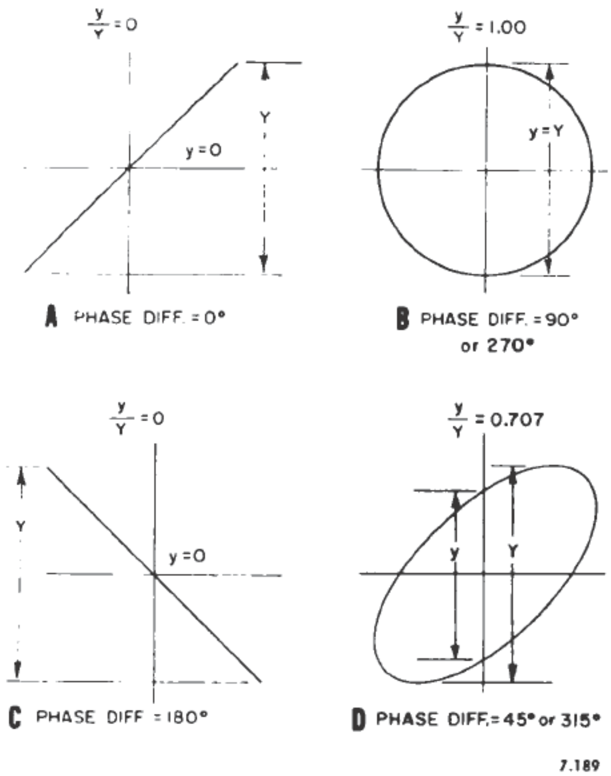

Figure 14-23.—Typical oscilloscope pattern for two sinusoidal voltages of same frequency.

This establishes a reference point with which we can compare test voltages.

It is necessary to determine in which direction the synchro shaft must be rotated to measure lead or lag. To do this, insert a phase lag network between the isolation transformer and the oscilloscope as shown in figure 14-22, and connect terminals V and 5. Rotate the synchro shaft until the same pattern is obtained as for the zero setting. The direction in which the shaft was rotated (clockwise or counterclockwise) is the direction in which the shaft must be rotated to measure a phase lag. Assume that a conventional compass card is used as the dial (to go from zero to increasingly higher numbers the dial is rotated counterclockwise), and that the synchro shaft must be rotated counterclockwise to measure a phase lag. (This direction of rotation depends on the order of the stator connections to the power line.) The calibration is made, using one power line phase and a network to determine the direction of rotation to measure a phase lag. From this measurement, the calibration of the other power line phases is known—120 degrees displaced. The positions of the three power line phases can be noted or marked on the dial, or a reference chart can be posted on the synchro phase shifter assembly.

Now that the phase shifter has been calibrated, measurements can be performed with the test setup as shown in figure 14-21. The output of the phase shifter is applied to the horizontal amplifier of the oscilloscope and the signal to be measured is applied to the vertical amplifier of the same unit. The magnitude of the voltage is measured with a conventional vacuum tube voltmeter. The phase shifter shaft is rotated until an in-phase pattern is obtained on the oscilloscope (a straight line of the slope previously determined). The phase of the signal with respect to the reference phase may be obtained from the phase shifter dial by taking the difference between (a) the phase shifter reading obtained for the in-phase reading, and (b) the phase shifter calibration for the reference phase with which the signal is to be compared. The phase shifter calibration will determine the sense (lead or lag) of this measurement.

ZEROING PROCEDURES

The following zeroing procedures should be used whenever it becomes necessary to zero any of the synchros in the system.

Heading Data Transmitter

When a synchro heading data transmitter has been replaced in the master unit:

1. Rotate the phantom and adapter ring until the transmitter alignment hole, shown in figure 14-24, is over the corresponding alignment hole in the starboard side of the spider.
2. Place the smooth shank of a 1/8-inch drill through the hole in the adapter ring into the hole in the spider. This is the mechanical zero position for the heading data transmitters.
3. Zero the synchro replacement according to instructions in OP 1303, "U. S. Navy Synchros."
4. Clamp the synchro in place and recheck the zero position. The null reading should not exceed 0.5 volts a-c.

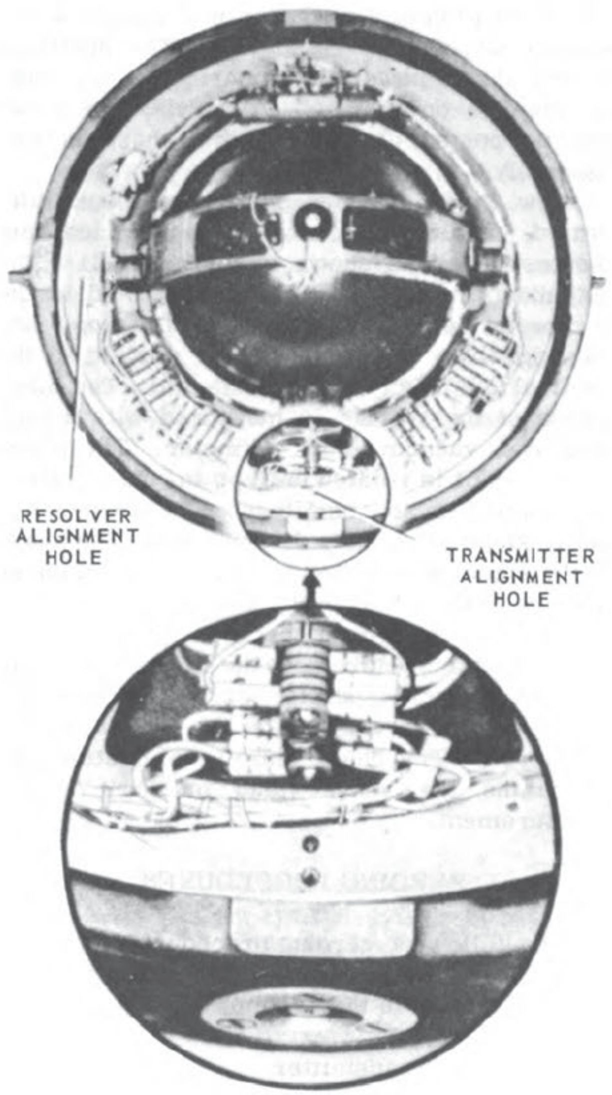

Figure 14-24.—Hole in adapter ring to be used for zeroing synchros after replacement.

5. Remove the drill and reassemble the binnacle.

Speed Resolver

When the speed resolver has been replaced in the master unit:

1. Rotate the phantom and adapter ring until the speed resolver alignment hole, shown in figure 14-24, is over the alignment hole in the starboard side of the spider.

2. Place the smooth shank of a 1/8-inch drill through the hole in the adapter ring into the hole in the spider. This is the mechanical zero position for the speed resolver.

3. Set the speed input knob manually until the speed dial reads 40 knots.

4. Connect an electronic voltmeter between leads S1 and S3. Loosen the synchro stator holding clamps and rotate the stator until the voltage is at a minimum. Reclamp synchro.

5. Remove the drill and rotate the phantom until the compass is on a north heading. Check the phase of the voltage between terminals S1 and S3. The voltage should be in-phase with respect to power line phase 1-3.

6. If the voltage is out-of-phase, repeat step 2.

7. Place a voltmeter on terminals S1 and S3 and again loosen the stator clamps. Then rotate the body of the synchro to the other minimum position and reclamp the synchro.

8. Repeat step 5. The voltage should now be in-phase.

Replacing Part in Speed Unit

After replacing the synchro or the potentiometer in the speed unit, the following procedure should be used: (Rotate the speed dial to zero position as indicated by pointer.)

Potentiometer R1

1. Loosen three clamp screws holding the potentiometer.

2. Connect the ohmmeter to potentiometer terminals 2 and 4.

3. With the dial on zero, rotate the potentiometer until zero resistance is read on the ohmmeter.

4. Clamp the potentiometer in position by tightening the clamp screws.

5. Rotate dial to the positions listed below and check the corresponding resistance values. These values should be within ± 5 percent.

Position	Resistance ohms
0	0
10	150
20	300
30	450
40	600

Synchro Motor B1

1. Zero the synchro in accordance with instructions in OP 1303, "U. S. Navy Synchros."

2. Place the synchro in position and rotate the synchro body until the voltage between S1 and S3 is less than 0.05 volts a-c, then clamp the synchro.

3. Recheck the dial zero position and null voltage.

QUIZ

1. What are the controlling factors in making the Mk 23 Mod 0 gyrocompass north-seeking?
2. What type of suspension is used by this gyrocompass?
3. How is the tilt of the gyro axle measured?
4. What are the signals called that are produced by the tilt signal amplifier?
5. From what components in the tilt signal amplifier is the meridian control signal developed?
6. Name the signals supplied to the azimuth control system.
7. Explain the function of the latitude switch.
8. What is the purpose of the balance adjustments?
9. In the vertical earth rate compensator what is the purpose of R33?
10. How is the grid of V9 excited?
11. For what other purpose is T6 used?
12. How is the overall gain of the azimuth control amplifier controlled?
13. What are the output elements of the azimuth control system which produce the torques applied to the gyro?
14. What is the phase relationship between the azimuth control amplifier output voltage and the reference field voltage?
15. Name the units of the leveling control system.
16. What signals do the leveling amplifier amplify?
17. How is the phase inversion accomplished for the push-pull operation in the leveling amplifier?
18. What is the output element that actually produces the torque which precesses the gyro about the vertical axis to a level position?
19. What kind of a circuit is used to detect the direction of tilt in the tilt meter circuit?
20. In the tilt meter circuit, what is the phase relationship between the signal voltage and the reference voltage?
21. In the voltage compensator, what is the objection to compensating for line voltage variations by regulating the power to the reference field and the excitation voltage for the signal sources?
22. What circuits are supplied with excitation voltage by the voltage compensating circuit?
23. How is the voltage that is impressed across the primary of T4 produced?
24. What is the purpose of the followup system?
25. In the followup pickoff system, what causes the armature to remain fixed?
26. What establishes whether the core was moved to the right or left in the pickoff circuit?
27. What is the effect of the rate signal?
28. How are the plates excited in the modulator?
29. What does the followup motor depend on for its direction and speed or rotation?
30. What are the three power supplies?
31. What is the normal starting time for the gyrocompass?
32. What are the first two steps to trouble-shooting?

CHAPTER 15

FRESNEL LENS OPTICAL LANDING SYSTEM

The Navy strives continuously to maintain the world's strongest and most efficient naval force. One of its most important fighting units is the carrier force. To keep this unit at top fighting efficiency, constant changes are necessary in airplane design. Today, heavier and faster naval aircraft are needed to accomplish this mission. Because these aircraft are heavier, a greater speed of approach is required. A plane approaching a modern carrier from approximately 1 mile has only 20 to 25 seconds before "touchdown." This short period does not allow a pilot receiving "paddle signals" sufficient time to react; therefore, a new and improved system of signals is necessary.

The first system of signals used by the Navy to assist the pilot in landing was the Mirror Optical Landing System. This system, however, proved inadequate. Its mirror was susceptible to reflected sunlight, and under adverse weather conditions visibility was limited. To correct these inadequacies, the Fresnel Lens Optical Landing System was designed. This Fresnel System will eventually replace the mirror system on all ships. It is the system described in this chapter.

Because the equipment is primarily electrical, the I. C. Electrician is responsible for the maintenance and repair of the system. The aim of this chapter is to provide the I. C. Electrician with this information. A review of IC3 concerning this equipment is recommended.

PRINCIPLES OF OPERATION

The Fresnel Lens Optical Landing System is a visual landing aid for pilots landing aboard aircraft carriers. It is basically an electro-optical system installed along the edge of the flight deck, which provides a bar of light to indicate to the pilot the correct angle of approach (glide path). The relative position of this bar of light, as indicated by its alignment with a horizontal reference line (datum lights), shows the pilot whether he is above, below, or on the correct glide path. The equipment is similar to the present Mirror Optical Landing System, the main difference being in the method of generating the bar of light. The Fresnel Lens Optical Landing System contains an integral light source which is projected by a system of lenses, whereas the Mirror Optical Landing System employs a separate light source and operates on the principle of reflected light.

A description of the physical makeup of the individual components of the Fresnel Lens Optical Landing System is included in the IC3 manual. This chapter, therefore, will be concerned primarily with the electrical circuits within the system.

The I. C. Electrician's most important responsibility concerning this equipment is the maintenance of the stabilization system, a discussion of which follows.

STABILIZATION SYSTEM

The computer, the lens box drive mechanism, and the servo amplifier enclosure are the major components that make up the stabilizing system (fig. 15-1), which maintains the light beam at a fixed angle with respect to the horizontal, regardless of the roll and pitch of the ship.

The roll and pitch receivers, located in the computer, receive 2-speed and 36-speed roll and pitch signals from the ship's stable element bus and convert these signals through the roll and pitch servo control amplifiers and servo motors (not shown) into mechanical shaft rotations.

The roll and pitch compensators convert servo mechanical shaft rotation into electrical signals that are fed into the basic angle receiver together with another electrical signal from the basic angle transmitter. These signals are combined and provide the input signal to the lens box drive mechanism. The lens box drive mechanism converts the signal through the deck edge servo control amplifier and a servo motor

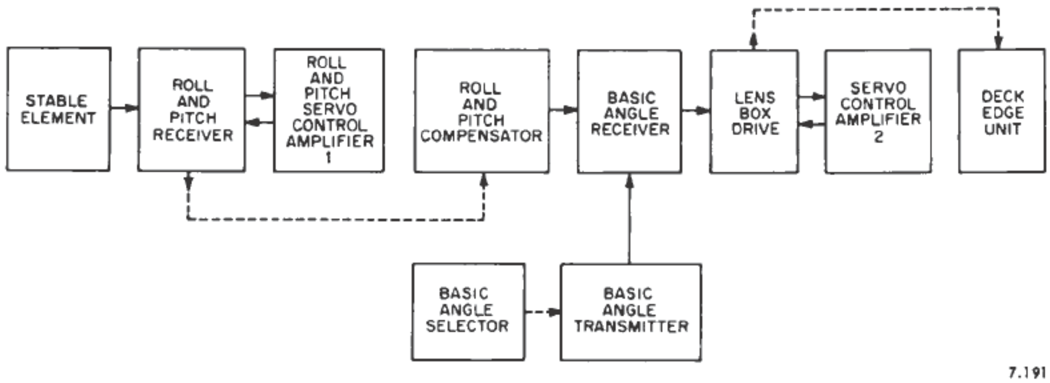

Figure 15-1.—Block diagram of stabilizing control circuit.

(not shown) into a mechanical signal that positions the deck edge unit.

The stabilization system consists principally of the following electrical components: (1) roll and pitch receiver (2-speed and 36-speed control transformers, tachometer-generator, limit switch, and servo motor); (2) roll and pitch compensator (mechanical differential and control transmitter); (3) lens box drive mechanism (servo motor, tachometer-generator, limit switch, and control transformer); (4) two servo amplifiers; (5) basic angle receiver; (6) basic angle transmitter; and (7) basic angle selector.

For simplicity in describing the operation of the system, only the roll stabilizing system and one of the deck edge units will be considered. The pitch stabilizing system operates in a manner similar to the roll stabilizing system. The deck edge units all operate in an identical manner.

The roll signal comes from the gyrocompass or ship's stable element bus (fig. 15-2) in the form of a 2-speed and a 36-speed synchro voltage signal. The signal is applied to the stators of the 2-speed and 36-speed control transformers (CT). The output signals are then combined in the crossover network and fed to the magnetic preamplifier, Z1. The output of Z1 has as its load the control windings of the magnetic power amplifier Z2. The servo motor B1 receives the output of Z2 and the resulting rotation of the servo motor shaft represents change in roll angle. The servo motor shaft is geared to the 2-speed and 36-speed CTs, the limit switch, the tachometer-generator, and the mechanical differential. The CTs are driven by B1 in a direction so that the output of the CTs tends toward zero. It is the combination of the electrical input from the ship's stable element and the mechanical feedback from B1 that creates a voltage input to the servo amplifiers Z1 and Z2 that keeps servo B1 following the roll of the ship.

The tachometer-generator 1 is coupled so that the electrical output, which is fed back to the amplifier Z1 provides a stabilizing reference signal for the magnetic amplifier.

A limit switch S1 is also operated by the servo shaft rotation. The limit switch opens the circuit to the servo drive motor B1 reference field on rolls greater than 12 degrees.

The shaft of the servo B1 is coupled to one other component, the mechanical differential, which converts the shaft rotation to the proper roll correction and drives a synchro control transmitter CX. The CX supplies a control differential transmitter CDX with an electrical signal. The CDX also receives a mechanical signal from a basic angle selector through a torque transmitter TX and a torque receiver TR. The resulting output of CDX is an electrical signal representing the basic angle setting and the roll correction. This electrical signal is the input to a CT and the CTs output signal is the input signal to servo control amplifiers Z3 and Z4 similar to the amplifiers previously mentioned. The output of the amplifier Z4 drives servo motor B2, the shaft of which is geared to one of the deck edge assemblies.

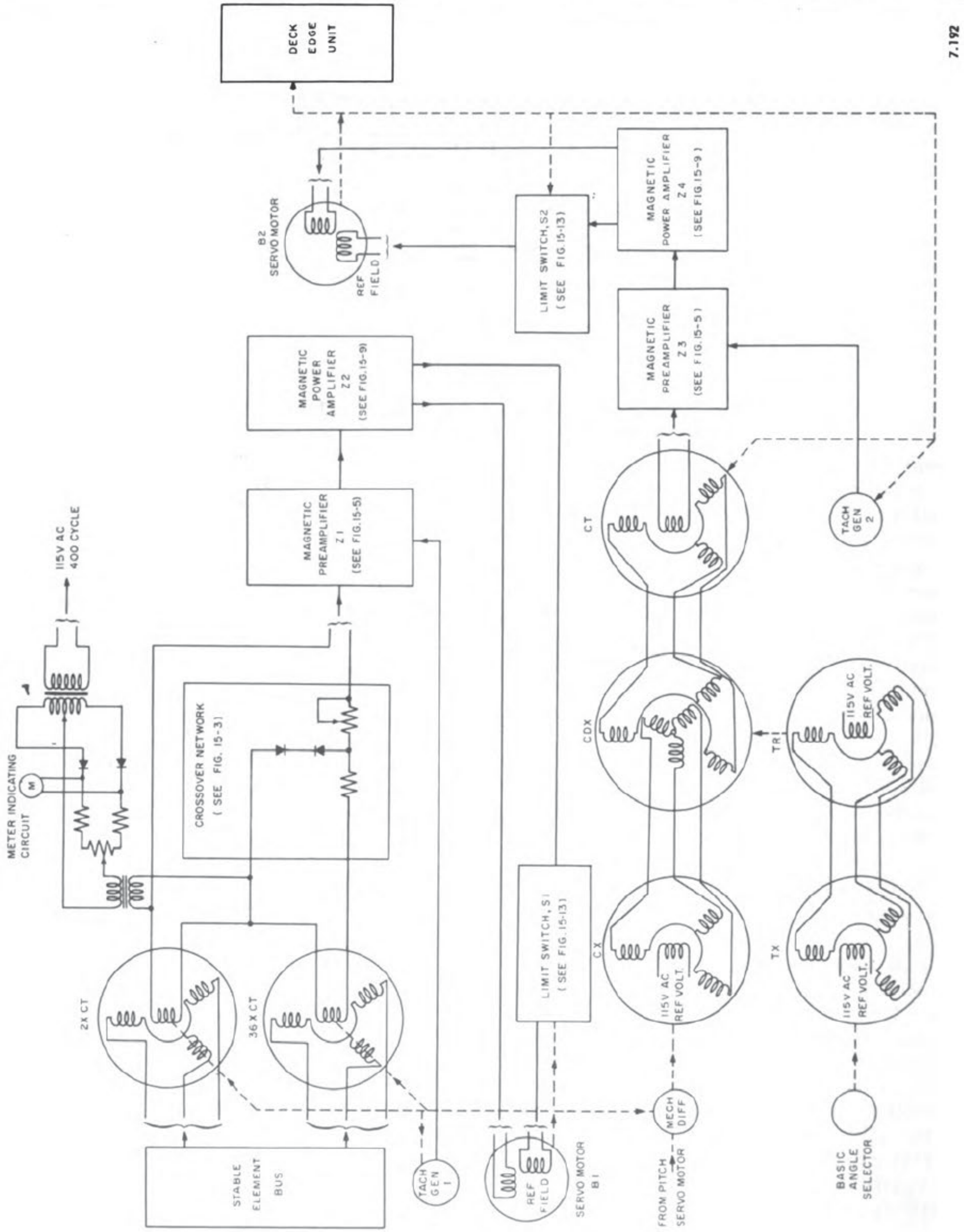

Figure 15-2.—Simplified schematic diagram stabilizing system, 115 v, a-c, 400 cycles.

The deck edge assembly is driven by servo B2 to the correct angle.

The above, in brief, is how the deck edge units are kept at a fixed angle with reference to the horizontal. A more detailed explanation of the stabilization system follows. Figure 15-2 should be used while studying the following explanations.

CROSSOVER NETWORK

The signal from the ship's bus stable element is impressed on the stator windings of the 2-speed and 36-speed roll CTs. The output of each CT is an error voltage from its rotor winding. The two signals are mixed in a cross-over network (fig. 15-3), which consists of two Zener diodes CR1 and CR2, a resistor R4, and a gain potentiometer R8. The characteristics of the two Zener diodes are such that the current flows in the reverse direction (anode -, cathode +) when 4 volts are applied to the diodes. Therefore, the voltage applied to Z1 from the 36-speed CT can never exceed ±4 volts due to the breakdown action of the diodes. This is a necessary condition for the proper operation of B1 as will be seen from the following discussion.

The voltage output of the 36-speed CT is $E_{36x} = 57.7 \sin \theta_{36}$ and the voltage output of the 2-speed CT is $E_{2x} = 57.5 \sin \theta_2$. This means that the 36-speed signal has $\frac{36}{2}$ or 18 nulls for each null of the 2-speed signal. Therefore, the instantaneous values (rms voltage at any given corresponding position of the two rotors) of the two signals usually are not the same (refer to voltage waveforms in fig. 15-4). For example,

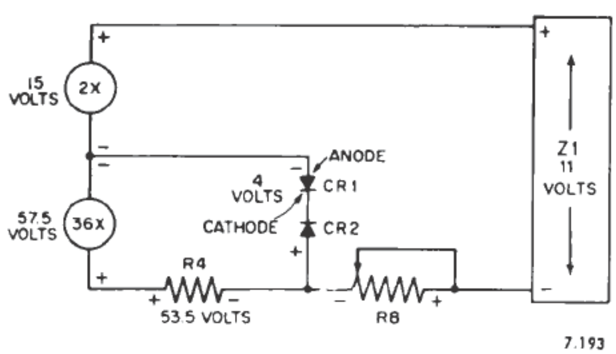

Figure 15-3.—Crossover network.

when $\theta_2 = 15°$

$$E_{2x} = 57.5 \sin 15° = 57.5 \times 0.259 = 15 \text{ volts}$$

when $\theta_{36} = 270°$

$$E_{36x} = 57.5 \sin 270° = 57.5\ (-1) = -57.5 \text{ volts}$$

The negative sign indicates a phase reversal of the 36x output voltage with respect to the 2x output voltage. The net voltage output to the preamplifier would be -57.5+15 or -42.5 volts, creating an unwanted phase reversal were it not for the operation of the crossover network. By applying the polarities and voltages as shown in figure 15-3, it is seen that the effect of the 36-speed signal is limited to -4 volts, the actual resulting voltage to the preamplifier is 15-4 or +11 volts, so there is no phase reversal. The low-speed signal combined with a small part of the high-speed signal is operative for large errors, while the more accurate high-speed signal becomes effective near zero error. Near 0°, E_{2x} is of negligible magnitude and the error voltage (0-4 v) is obtained from the 36x CT. The Zener diodes act like an open circuit and the 36x output is applied across the Z1 input in series with the 2-speed CT rotor.

SERVO AMPLIFIER

The servo amplifier consists of the preamplifier Z1 and the power amplifier Z2. The combined signal from the cross-over network is one of the inputs to Z1. This signal is impressed across terminals 1 and 7 as shown in figure 15-5.

Preamplifier Z1

To understand how Z1 functions, consider first the type of circuit being used. It is a fast response bridge circuit formed by coils B, C, E, and F, wound on toroidal magnetic cores and includes rectifiers CR5, 6, 7, and 8. The control windings of Z2 act as the load on Z1. To ensure proper phasing, the bridge must be supplied from the same generator that supplies the ship's bus stable element.

Analysis of Preamplifier Z1

If there is no input signal from the 2-speed and 36-speed CTs (fig. 15-6), the only input is the reference voltage. On one half of the cycle, the reference voltage circuit is from terminal 5

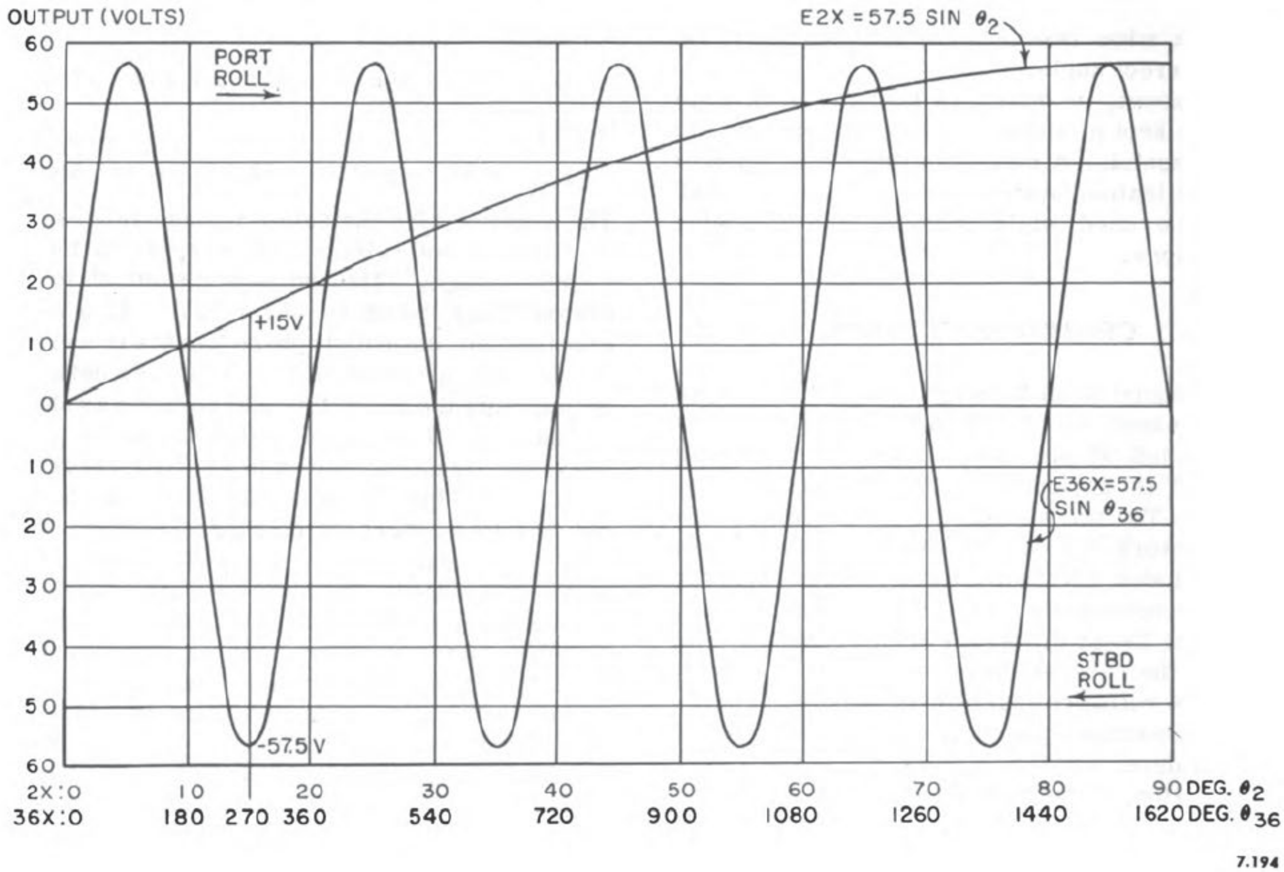

Figure 15-4.—2- and 36-speed voltage waveforms.

up through the two parallel sets of coils and rectifiers and back to terminal 2. The bridge is balanced and no signal flows through the control windings of Z2. On the next half of the cycle, the circuit is from terminal 2, down through rectifier CR9 to R11. From R11 there are two parallel paths, one through R9 and part of coil F, and the other through R10 and part of coil E, and back to terminal 5. The purpose of the circuit for the latter half cycle is to create a mmf opposite to that created on the first half of the cycle. This opposing mmf helps demagnetize the core and resets the core for the following half cycle.

Consider the circuit once again, this time with an input signal from the 2-speed and 36-speed CTs to terminals 1 and 7 of Z1. Assume that the signal from the 2-speed and 36-speed CTs is negative at terminal 1 (polarity for a port roll) at the same instant that the voltage at terminal 5 is negative. The polarities will then be as indicated in figure 15-7. The direction of the created mmf is shown by the arrows.

The relation between the polarity marks (dots on the coils) and the direction of the mmf arrows is based on the following assumptions: If electron flow is INTO the dotted end of the coil, the mmf arrow points UP. If the electron flow is OUT of the dotted end of the coil, the mmf arrow points DOWN. The mmf in coils A and B will be opposing while the mmf in coils C and D will be aiding. When coils C and D aid, they saturate core 2. This means that the impedance is lowered and more current is permitted to flow. When more current flows, point G becomes more positive than point H. Therefore, part of the current at point H flows through the control windings of Z2 back to point G, up through coil C, and back to terminal 2. This is called the "gating" half cycle. On the

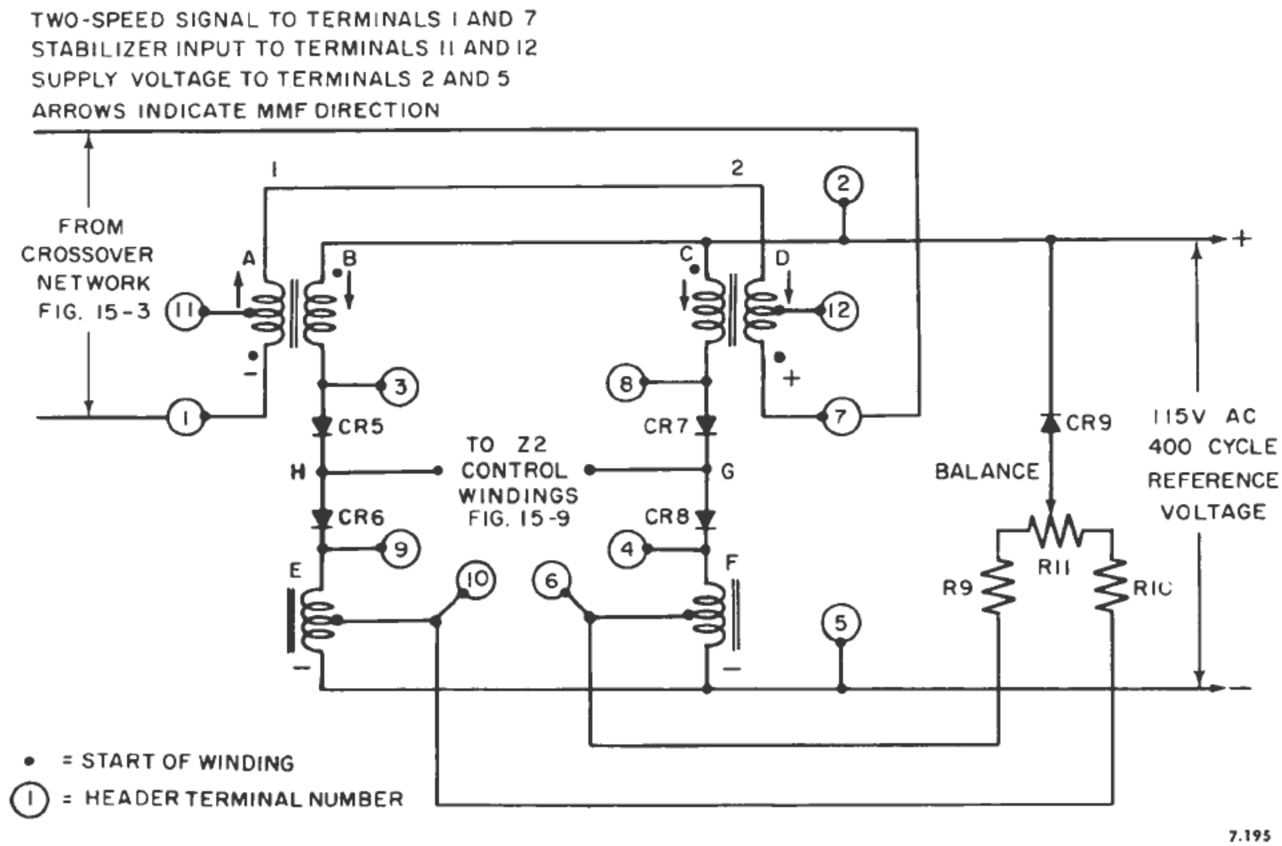

Figure 15-5.—Simplified schematic of preamplifier.

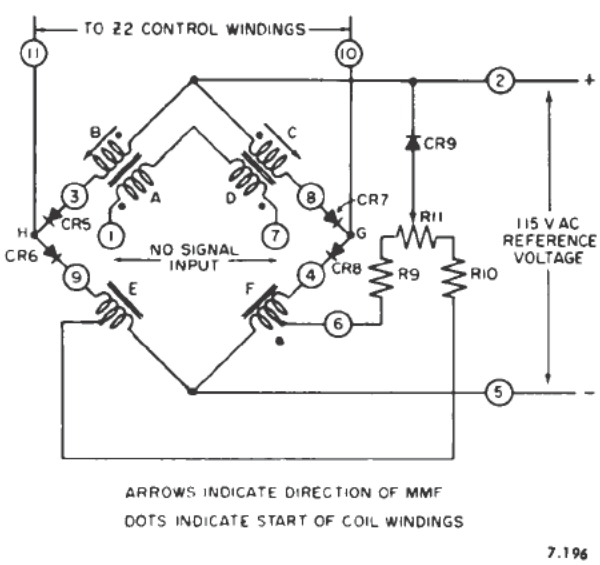

Figure 15-6.—Simplified schematic diagram of preamplifier with no input signal.

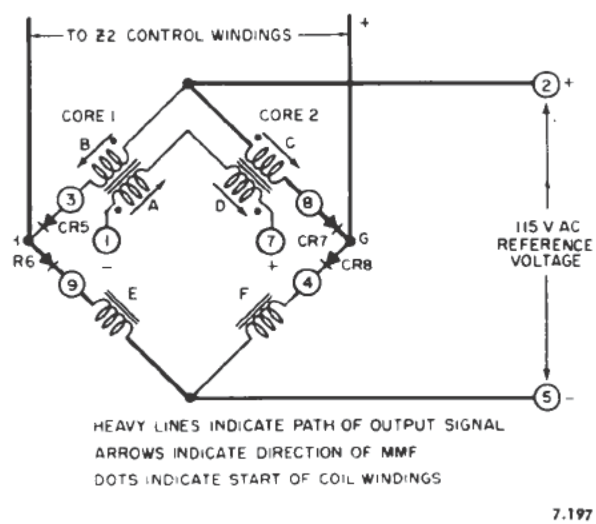

Figure 15-7.—Simplified schematic diagram of preamplifier with input signal for a port roll.

alternate half cycle, the reset circuit previously described (fig. 15-6) operates and prepares the coils for the next productive half of the following cycle.

For a starboard roll (fig. 15-8) the polarity of the signal from the 2-speed and 36-speed CTs would be negative at terminal 7 because the phase of the CTs reverse with respect to the reference voltage as the direction of displacement reverses. This would mean that point H would become more positive than point G and the flow through the control windings of Z2 would be reversed.

Power Amplifier Z2

The input to Z2 is the output of Z1. This signal is impressed across terminals 10 and 11 of Z2 as shown in figure 15-9. The power amplifier Z2 consists of 4 toroidal magnetic cores (A, B, C, and D), 8 diodes, a power transformer T11, 2 balancing resistors, and 2 capacitors. A close look at the circuit in the power amplifier reveals 2 bridges as shown in figure 15-10. One bridge is formed by T11 representing 2 of the legs, and coils 17 and 20 representing the other 2 legs. A second bridge is formed by T11 and coils 18 and 19. Servo motor B1 is the load for both bridges and is across the center-tap of T11 and terminal 3. The first bridge functions during a port roll and the other during a starboard roll. In figure 15-10, however, the

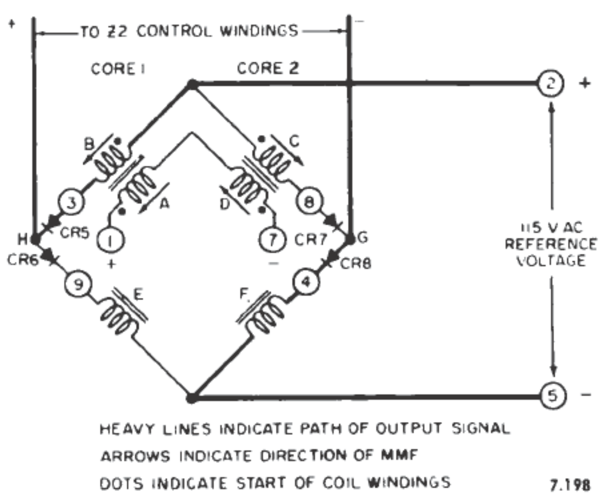

Figure 15-8.—Simplified schematic diagram of preamplifier with input signal for a starboard roll.

bridge is assumed to be balanced with no signal from Z1.

Analysis of Power Amplifier

During the half cycle that Z1 is resetting, no signal appears across terminals 10 and 11. The mmfs in all the magnetic cores of Z2 are equal, therefore, no voltage appears across B1. With a signal from Z1, across terminals 10 and 11, however, the balance of the bridge circuit is upset and current will flow through B1. Consider terminal 11 as being the negative terminal when a signal is coming from Z1 during a port roll as shown in figure 15-11. This signal is impressed across the control windings of Z2 and sets up an mmf pattern, as indicated by the arrows. It is evident, when we consider the mmf arrows set up by the control windings and the bias windings in Z2 in relation to the instantaneous polarity of T11, that magnetic core D is the only magnetic core that has a flux field aided by all three windings (bias windings are not shown in figure 15-11). This means that the core is saturated and the impedance is lowered in coil 20. More current is permitted to flow from terminal 22 through rectifier CR3, down through coil 20, out terminal 3, through B1, and back to terminal 21 of T11.

On the second half cycle of the T11 and T5 output when all polarities are reversed, current flow in Z1 is blocked by its rectifiers and there is no signal applied to Z2 (fig. 15-6, polarities reversed).

If we consider the previous active half cycle as representing a signal for a port roll, then the signal for a starboard roll will reverse the polarity of Z2 with respect to that of T11. Assume that terminal 10 of Z2 is now the negative terminal for the output signal of Z1, as shown in figure 15-12. Again, the control windings will be the deciding factor in determining which magnetic core will saturate. The mmfs are aiding in core A and opposing in core D, so core A will saturate. The impedance of coil 17 is lowered and more current flows through it. The imbalance will cause current to flow from terminal 21 of T11 down through B1 (opposite to the direction of flow for the port roll) back out terminal 3, up through coil 17, through CR4, and back to terminal 16 of T11. It is apparent then, that B1 rotates in one direction for a port roll, and in the opposite direction for a starboard

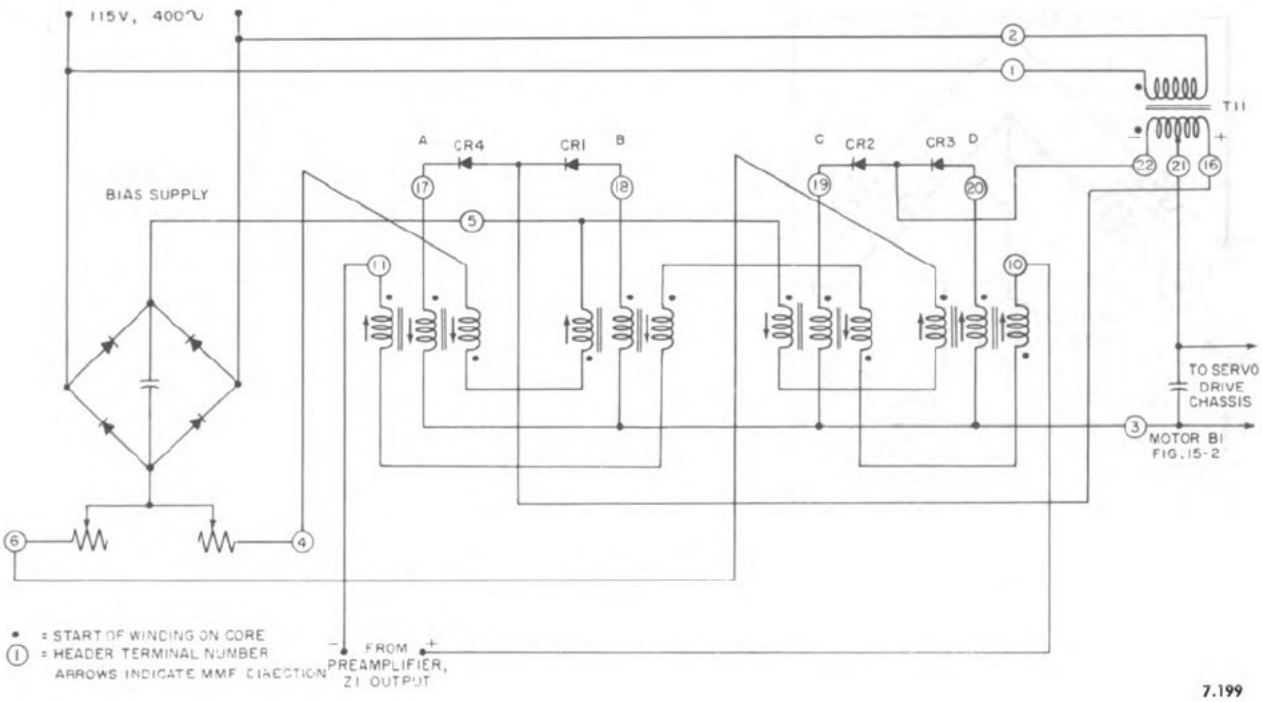

Figure 15-9.—Simplified schematic of power amplifier (Z2); port roll.

roll, since the inputs to the control field are reversed with respect to the reference field each time the roll changes direction.

The full wave rectifier (left side of fig. 15-9) is provided to supply d-c voltage for one winding on each of the four cores. This d-c voltage is a bias voltage which sets the operating point for the amplifier. The direction and magnitude of the control signal then determines when and how much current will be supplied to the load.

SERVO MOTOR B1

The servo motor B1 (fig. 15-2) performs four functions. First, it drives 2-speed and 36-speed CTs in a direction that makes their output tend toward zero. Second, the B1 drives a tachometer-generator which has a d-c output signal. This signal is fed to terminals 11 and 12 of Z1. The purpose of this feedback is for stabilization of the unit. It does this by opposing the mmf which has already been set up by the signal of the 2-speed and 36-speed CTs. The third function of B1 is to drive the gearing which operates the limit switch S. Operation of this switch removes power from B1 when its maximum limit has been reached. The fourth function of B1 is to provide an input for the roll compensator.

ROLL COMPENSATOR

The roll compensator is made up of a mechanical differential and a control transmitter CX. The purpose of the mechanical differential is to convert B1 shaft rotations into the proper roll correction. This is necessary since the three deck edge assemblies are located at different distances from the roll axes of the ship.

The proper roll corrections are determined for each deck edge assembly by the following relationship:

$$\text{Roll correction} = (\text{roll angle}) \frac{S}{2500 \text{ ft.}},\ \text{where}$$

S equals the horizontal distance between the roll axis of the ship and the point where the center line of the beam of light will intersect a vertical plane 2500 feet aft of the lens unit.

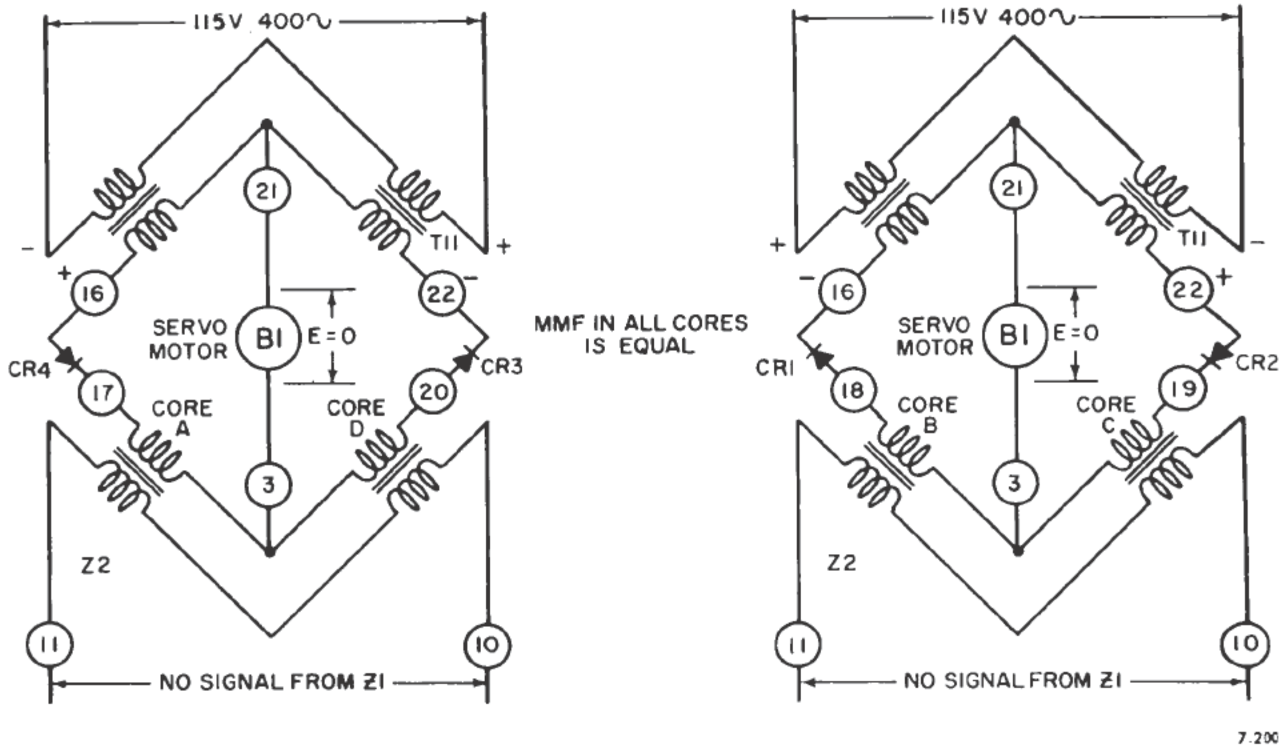

Figure 15-10.—Simplified schematic diagrams of power amplifier bridge circuits for each half cycle with T11 the only input.

The output of the mechanical differential drives the rotor of CX.

BASIC ANGLE RECEIVER

The basic angle receiver is made up of two components, a control differential transmitter CDX, and a torque receiver TR (fig. 15-2). The electrical output of CX is combined in CDX, along with a mechanical output from TR. The input to TR is an electrical signal representing the desired basic angle. It is received from the basic angle transmitter TX, via the basic angle selector switch (not shown).

LENS BOX SERVO DRIVE MECHANISM

The lens box drive mechanism consists of a CT, tachometer-generator 2, servo motor B2, servo limit switch S2, and magnetic servo amplifiers Z3 and Z4.

The CT receives the electrical signal from the CDX in the basic angle receiver. This signal is then converted into a shaft rotation representing the combined basic angle and roll correction necessary to properly position the lens assembly.

The output shaft rotation of B2 drives a worm gear, which in turn, drives a 20 degree segment gear. It is the rotation of the segment gear through its arc of 20 degrees that positions the reference light and lens assembly properly with respect to the flight deck.

LIMIT STOP OPERATION

Mechanical means to limit travel has been incorporated into the gearing of all servo units. To prevent damage to the gear train when this limit is reached, circuitry has been included to remove power from the servo drive motor reference field just before the stop becomes effective. Continuous operation is obtained by the phase-sensitive characteristics of the circuit. The circuit removes power to the servo

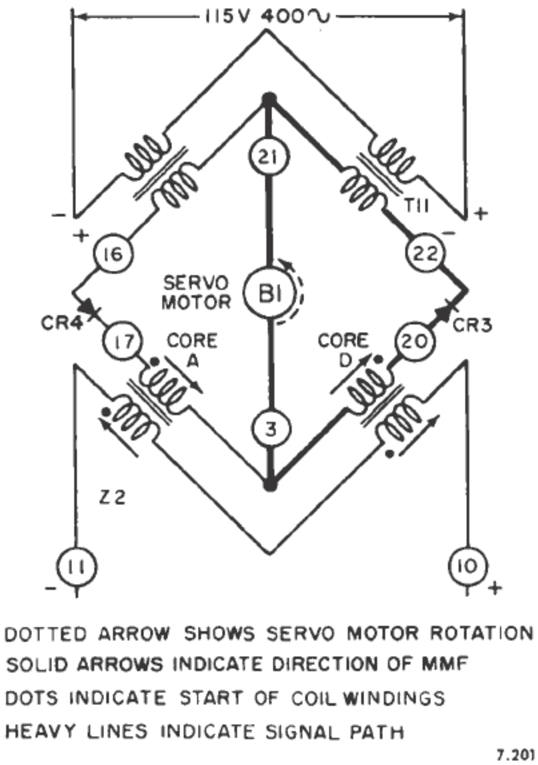

Figure 15-11.—Simplified schematic diagram of power amplifier bridge circuit with input signal for a port roll.

motors when receiving excessive roll (further-into-the-stop) signals and returns voltage to the motor fields when the reversing roll (out-of-the-stop) signals are being received.

The action of the limit controls is explained with reference to figure 15-13. S1 and S2 are microswitches actuated by cams in the servo gearing. They are normally in position 1 and move to position 2 when depressed by a cam which is operated when an excessive roll occurs either to port or starboard.

The arm of K1 oscillates between positions A and B in synchronism with the stabilizing rotations of B1. The position of K1 during any tracking motion will not shunt the mechanical limit switch being approached. This orientation of relay K1 and limit switches S1 and S2 makes possible the removal of power from the motor reference field when the cam changes the limit switch from position 1 to position 2.

Transformer T1 makes the phase-sensitive operation of K1 possible. T1 receives voltages from both the 115-volt 400-cycle reference line and the phase-sensitive output voltage to magnetic amplifier Z2. Potentials from these sources add or cancel (depending on whether or not Z2 output is in-phase with the reference 115-volt line) in T1 to produce a voltage which either energizes or does not energize K1. When not energized, the arm is held in position A. Thus, K1 is either in position A or B, depending on the phase-sensitive voltage from Z2. Since the phase of the voltage from Z2 controls the direction of rotation of B1, the relationship of K1's position and the limit stop action is interlocked. For example, when the servo gear train cam is approaching limit S1, the relay arm moves to position B (Z2 output and reference voltage add). When the gear train cam is approaching limit S2, the relay arm moves to position A (Z2 output subtracts from reference voltage).

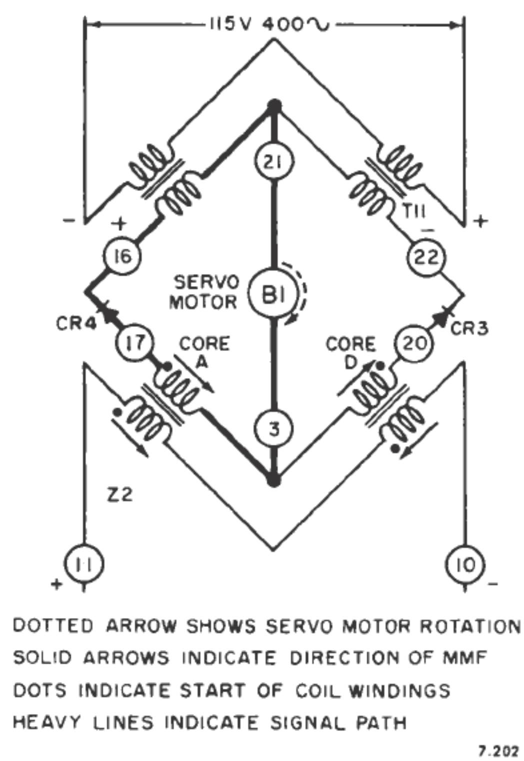

Figure 15-12.—Simplified schematic diagram of power amplifier bridge circuit with input signal for a starboard voltage.

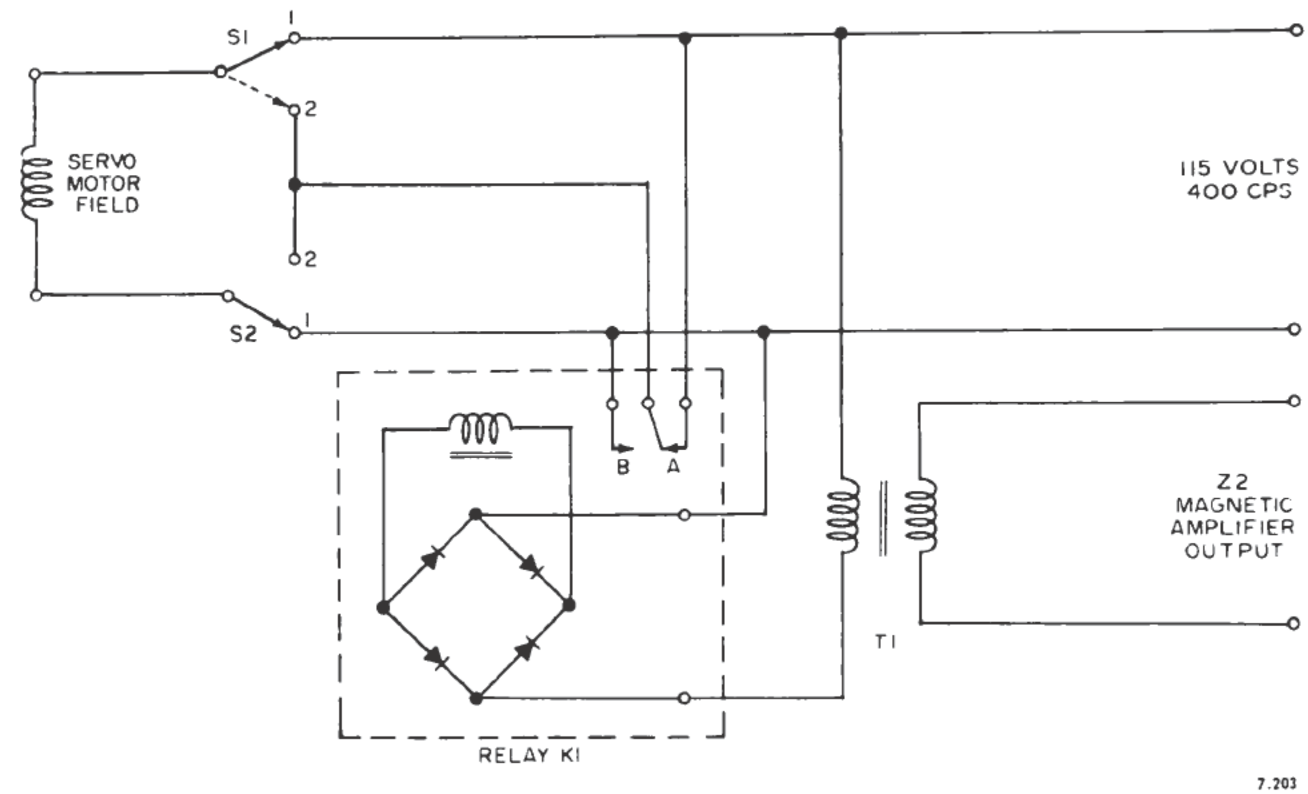

Figure 15-13.—Simplified schematic of limit switch circuit.

Consider the circuit when the limit switch is set for ±12 degrees and the ship is rolling more than 12 degrees. Assume that the servo gear train is approaching S1. The voltages from the reference line and the magnetic amplifier Z2, are in-phase addition, increasing the strength of the coil of relay K1, and moving the arm to position B. When the servo train reaches the limit, S1 moves to position 2.

When S1 moves to position 2, two things happen. First, power is removed from the motor field; and second, a short circuit is applied across the field preventing any single-phasing action of B1. B1 then coasts to a halt against the mechanical limit. If the signal were greater than 12 degrees, B1 would remain braked in this position until the signal reached its maximum, reversed, and came back within the normal 12 degree range.

When the signal returns within 12 degrees, the following sequence takes place to return B1 to normal operation: (1) the output of Z2 changes phase by 180 degrees, weakening the coil of relay K1 and causing the arm to move from B to A; (2) S1 (in position 2) is shunted and the line voltage to the motor's reference field is reconnected (the servo system now follows any signal within limits); and (3) when B1 moves back from the limit switch, S1 returns to position 1 re-establishing normal static connections.

The functioning of all the limit switches in the drive units and the roll and pitch servos are identical.

ERROR INDICATING CIRCUIT

The error indicating circuit (fig. 15-14) gives a visual indication of the positional error of the servo system which it is monitoring.

The circuit is balanced by disconnecting the primary leads of T4 and adjusting R3 so that the meter reads zero. The adjustment of R3 sets the voltage across R1 and the upper part of R3 equal and opposite in phase to the voltage across R2 and the lower part of R3. With T4 reconnected, an error signal from the 2-speed

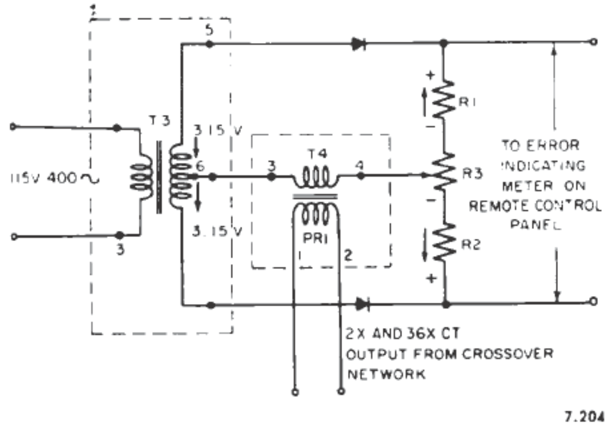

Figure 15-14.—Simplified schematic of error detection circuit.

and 36-speed CTs will unbalance the voltages across R1, R2, and R3 at any instant by adding the T4 output to half the T3 output in one part of the circuit and subtracting the outputs in another part of the circuit. The indicating meter is a permanent magnet moving coil d-c type having a central zero.

Assume first that on a starboard roll the reference voltage from T3 and the CT output voltage from T4 have the polarities indicated in figure 15-15, A, for the first half cycle and in figure 15-15, B, for the second half cycle. Although the imbalance is opposite for the two half cycles, the voltage across R2 and the left half of R3 (fig. 15-15, B) is the larger of the voltage drops because it is the sum of the two components, and the deflection is to the left. The meter indicates the average value of this current.

For a port roll the polarity of the CT output voltage from T4 (fig. 15-15, C) is reversed with respect to its polarity, in figure 15-15, A. The polarities for the first half cycle are indicated in figure 15-15, C, and for the second half cycle in figure 15-15, D. Although the imbalance is again opposite for the two half cycles, the larger voltage is across R1 and the right half of R3 (fig. 15-15, C) because it is the sum of the two components, and now the deflection is to the right. Again, the meter indicates the average value of this current.

LIGHTING SYSTEM

The lighting system is another important responsibility of the I. C. Electrician. This is a 60-cycle 115-volt a-c 3-phase system supplied from the ship's service generators. Power is brought into the system through a 100-ampere 3-phase circuit breaker. Five smaller 60-cycle 1-phase circuit breakers deliver power to the various lighting and control components (fig. 15-16, A and B).

DIMMER CONTROL SYSTEM

The brightness of the different lighting circuits is controlled by magnetic amplifier dimmers. For night flying, the system enables an operator to vary the intensity of the different lights on steps 1 through 6. Step 7 is directly across the lines. The lights can be controlled from either the primary fly control station or the flight deck lighting control station consoles. When a desired lighting circuit is switched on, the rheostat control circuit and the dimmer power circuit is energized. The intensity of the lights is now controlled by varying control rheostats (not shown) from either control console.

The reactors in the dimmer are connected as a self-saturating circuit. This arrangement produces a low power loss variable impedance which is used to provide a variable voltage supply. The impedance is changed by varying the current in the control windings of the reactors with the control rheostats in the console unit. The change in impedance determines the voltage to the lighting circuit and the intensity of the lights. The effective impedance depends on the time in the cycle that the core saturates. If saturation occurs early in the cycle, there is only a small flux change and small effective impedance. For this condition the output voltage to the lights is relatively high. Conversely, when the core saturates late in the cycle, the flux change and effective impedance are large. Voltage to the load is small and the lights dim.

REMOTE CONTROL PANEL SELECTION

Selection of one of the two remote control panels to operate the entire system is made by operating the remote control panel selector switch located on the power panel. This switch is a 48-pole 3-position 5-ampere 125-volt rotary switch. Complete isolation of a remote control panel, in the event of battle damage, can be obtained by the use of this switch.

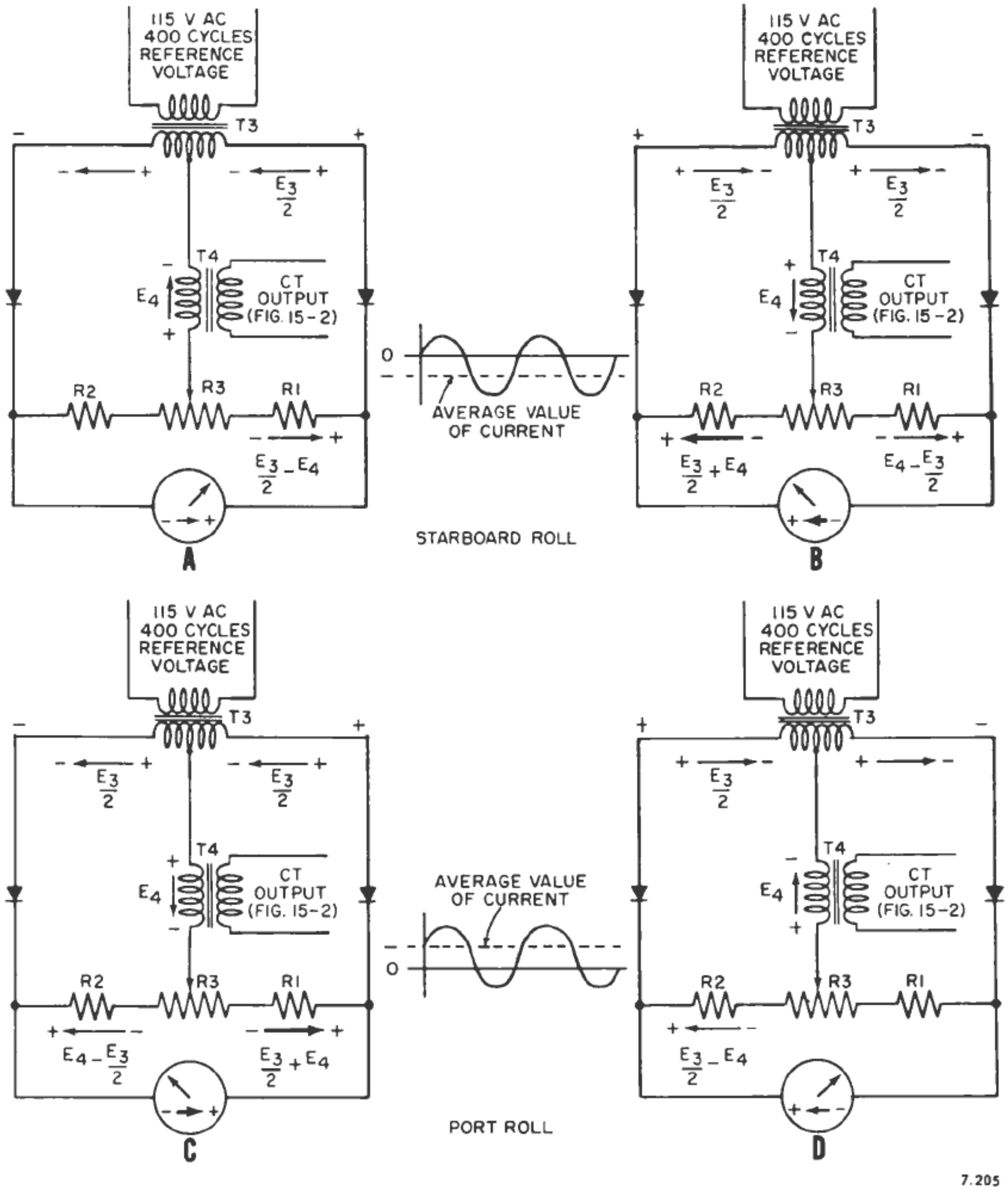

Figure 15-15.—Simplified schematic of error detection circuit for port and starboard roll.

A unit selector switch also located in the panel is used to select the proper deck edge unit for a particular type aircraft. This switch is a rotary locking 2-pole 4-position switch.

BRIGHTNESS SELECTION

The brightness of the reference, datum, waveoff, and cut lights is selected by the brightness selector switch. This is an 8-position

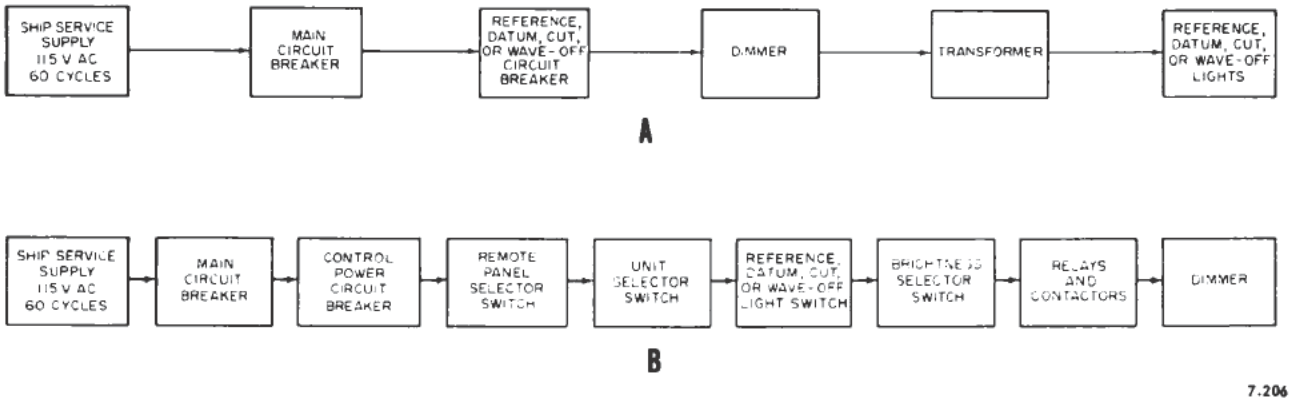

Figure 15-16.—Block diagram of (a) main power circuits, and (b) control circuits for reference, datum, cut, and waveoff lights steps 1 through 6.

single-pole switch which operates a group of relays and contacts to adjust the lighting system to the approximate brightness desired. The lights have seven degrees of brightness.

For steps 1 through 6, the brightness is further controlled by adjusting the voltage to the lights by using magnetic amplifier dimmers and dimmer control rheostats.

Step 7 is connected directly across the line. The output voltage of the dimmers is a function of the magnitude of the a-c voltage across the dimmer control terminals. The various dimmer control voltages are obtained for steps 1 through 6 by placing various pre-set rheostats in series with the 115-volt a-c line voltage and the dimmer control terminals. Twenty-four contactors and 25 rheostats are needed to obtain 6 different control voltages for each of 4 dimmers. In addition, separate control rheostats are necessary to obtain the flexibility required to get the precise brightness of each dimmer at each brightness step.

In the cases of the datum, waveoff, and cut lights which utilize 115-volt lamps, it is necessary to use power matching transformers between the dimmers and the lamp load. These power matching transformers are autotransformers with taps around the 70 percent voltage point to permit optimum power matching.

The reference light transformers serve a double purpose. They provide the necessary power matching through step 6. In addition to the power match, however, they must provide 115/60 volt stepdown for step 7 operation, since the reference lamps are operated 5 in series of 12 volts per lamp for a total of 60 volts. Operation of the lights in series causes the lights to age at the same rate.

REFERENCE LIGHT OPERATION

The operation of the reference lights must be considered under three separate conditions: (1) normal (non-waveoff) step 7; (2) normal (non-waveoff) steps 1 through 6; and (3) waveoff either steps 1 through 6, or step 7.

In all the above cases, it is assumed that all circuit breakers and the reference light switch are closed and that selection of a remote control panel and a deck edge unit has been made.

Analysis of Condition 1 Normal (Non-waveoff) Step 7

A schematic diagram of the reference light circuit under condition 1 only, is shown in figure 15-17. As stated above, all circuit breakers and switches have been set for condition 1 operation.

When the brightness selector switch is placed on step 7, it causes relay K2 to energize. K2 closes its normally open contact, K2G. This action energizes relay K3, which closes its normally open contact K3A, and places the primary of transformer T1 across the line. Relay K2 also opens its normally closed contact K2A, which keeps relay K1 deenergized. This action, together with the closing of contact K3A, allows the dimmer to be bypassed and the power to be placed directly across T1.

Relay K4, which was energized when condition 1 was set up, closes its two normally open

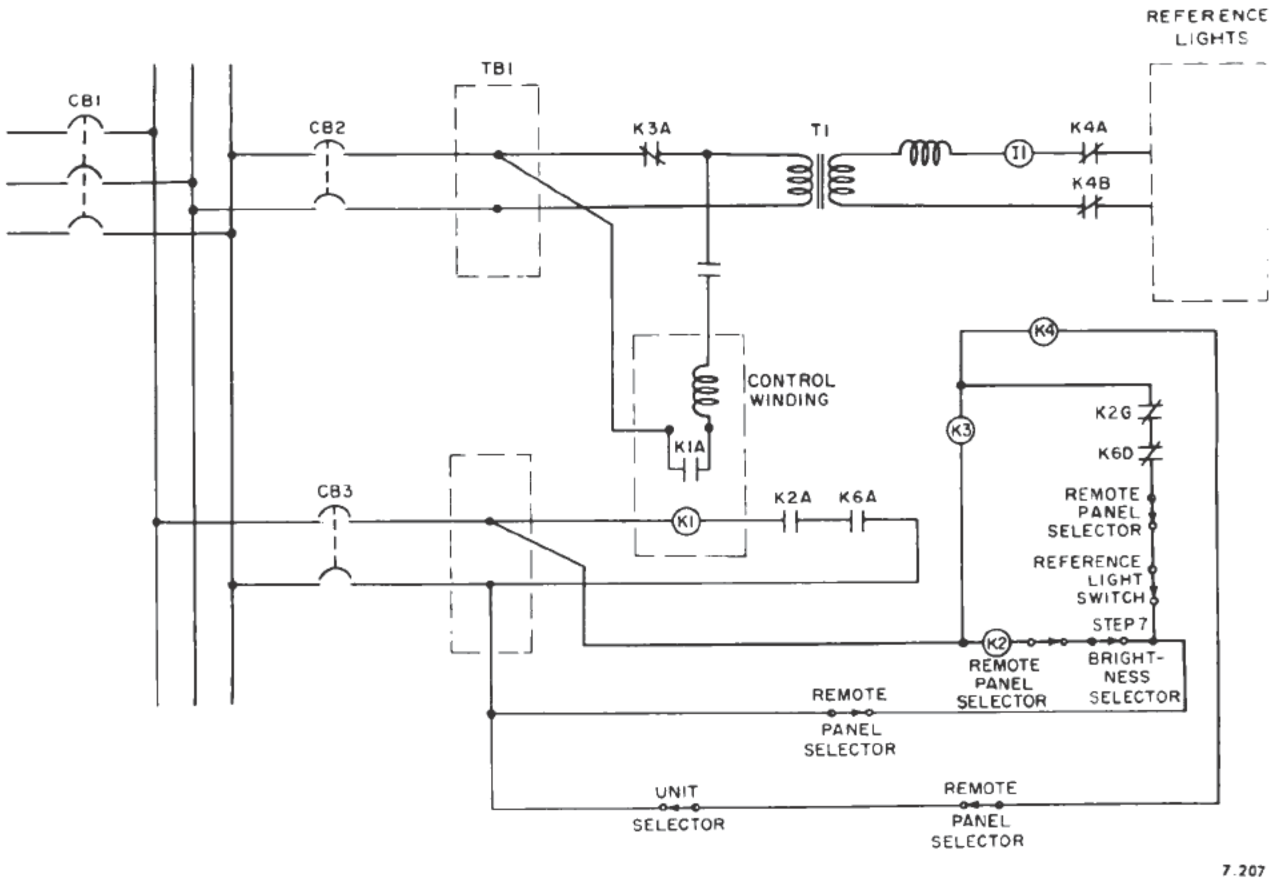

Figure 15-17.—Simplified schematic of reference light circuit step 7 (normal non-waveoff).

contacts K4A and K4B. This action makes power available directly to the reference lights.

Condition 2

Under condition 2, the dimmer is no longer bypassed. When the brightness selector switch is set on any of steps 1 through 6, it operates the necessary relays, placing the proper resistance in series with the dimmer control winding. The power to the selected deck edge unit is now controlled by the dimmer.

Condition 3

Condition 3 provides for a waveoff situation. When the waveoff switch is operated by the LSO, a synchronous pulsator motor is turned on. This motor drives a cam which pulses an ON-OFF switch. Should the ON-OFF switch stop in the open position, a normally closed contact (open during waveoff) shorts the switch when the system is operating in a non-waveoff condition.

The flashing of the reference lights is 180 degrees out-of-phase with the flashing of the waveoff lights. The flashing is at 85 to 95 flashes per minute.

DATUM LIGHT OPERATION

Datum light operation must also be considered under three separate conditions: (1) normal (non-waveoff) step 7; (2) normal non-waveoff steps 1 through 6; and (3) waveoff all steps.

In all the above cases, it is again assumed that all circuit breakers and the datum light switch are closed, and that selection of a remote control panel and a deck edge unit has been made.

Under condition 1, the brightness selector switch, when moved to step 7, operates a group of relays and contactors. This action causes the datum light dimmer and the transformer to be bypassed. Power is applied directly to the deck edge unit previously selected.

Under condition 2, as in the reference light operation, neither the dimmer nor the transformer is bypassed. This means that the power to the lights is controlled by the dimmer. The degree of control depends on the position of the brightness switch.

Operation of the waveoff switch during condition 3 energizes the necessary relays and contactors to de-energize the conditional datum lights.

WAVEOFF LIGHT OPERATION

Waveoff light operation need be considered under only two different conditions: (1) step 7, and (2) steps 1 through 6.

It is assumed that all circuit breakers are closed, the waveoff light button on the waveoff switch is operated, and that selection of a remote control panel and a deck edge unit has been made.

Under condition 1, a group of relays is energized by step 7 of the brightness selector switch and the waveoff button. The pulsator motor is energized and drives a cam which pulses the circuit. The closing of the pulsing contacts bypasses the power around the waveoff dimmer and transformer to the appropriate contacts of the deck edge unit previously selected.

Condition 2, as in the reference light and datum light operations, does not bypass the dimmer nor the transformer. The dimmer controls the power to the lights according to which step 1 through 6 has been selected. Again, the pulsator motor is energized and operates a cam to pulse the circuit. The flashing of the waveoff lights is 180 degrees out-of-phase with the reference lights.

CUT LIGHT OPERATION

The cut light operation is used to signal the pilot when to cut power to his engine. It, too, need be considered under only two conditions: (1) normal (non-waveoff) step 7, and (2) normal (non-waveoff) steps 1 through 6.

In the above cases, it is assumed that all circuit breakers are closed, the cut light button on the cut light switch is operated, and selection of a remote control panel and a deck edge unit has been made.

Under condition 1, certain relays and contacts are energized by the operation of the brightness selector switch and the cut button on the cut light switch. These particular relays and contacts when energized cause power to bypass the dimmer and the transformer. This places full rated cut light power at the deck edge unit selected.

Again under condition 2, the dimmer voltage is determined by the position of the brightness switch which operates the necessary relays to place the proper resistance in series with the dimmer. The dimmer then regulates the power to the lights.

MONITORING IN THE LIGHT SYSTEM

Because of the importance of the reference lights to the landing system, it is obvious that effective monitoring must be used. Therefore, to warn against failure or improper functioning of the system, the various operations are monitored.

All of the monitoring devices are visual and consist of meters, indicating lamps, and indicating fuses.

There are three reference light lines (fig. 15-18), each containing one lamp from each of the five cells. The five lamps are in series and the lamps for each line are in a vertical column. The image of the three reference lamp filaments on any one cell as seen through the lenticular lens is a continuous bar of light or a blend of light from the three lamps.

The effect of the failure of any one of the three lamps is a dimming of the light bar. This dimming is not an obvious effect and may be mistaken for operation at a lower step of brightness if noticed at all.

Therefore, to warn against lamp failure, a special monitoring circuit (fig. 15-19) is inserted in the reference light line. The circuit is basically a sensitive relay. Relay K7 is driven by a current transformer T2, whose primary is in series with the reference lamps. As long as the current in the line is greater than or equal to 4.8 amperes (step 1 reference light current), the relay will be energized and

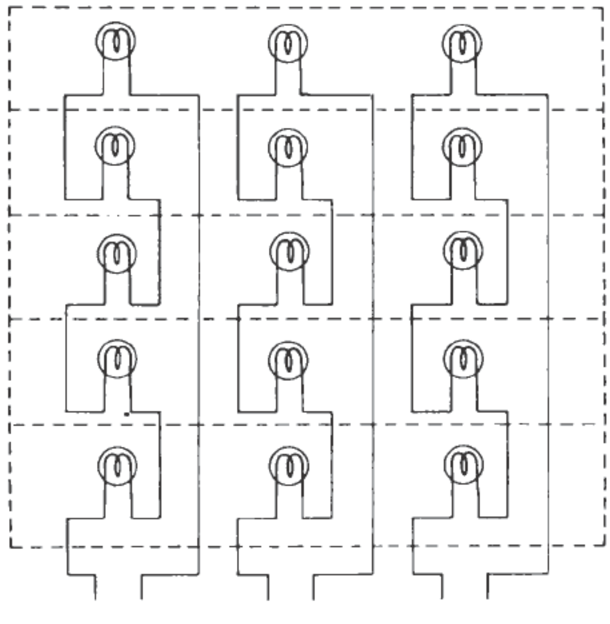

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Figure 15-18.—Reference light lines. Three groups of five lamps in series.

the appropriate reference light monitor indicating lamp will be lit at the remote control panel.

To warn against excessive current, an ammeter is inserted in each reference light line. The meter will indicate when the current exceeds 13.5 amperes. If this current (13.5 amperes) is exceeded, the reference light line components are damaged, the envelopes are blackened, and the filaments are distorted. This means the group of lamps affected must be replaced.

During waveoff operation, the reference light monitor indicators and the ammeters will follow the flashing reference lights.

Waveoff Monitoring

Waveoff monitoring is accomplished by a lamp on the remote control panel. The lamp is energized by the closing and opening of the pulsator contact on the power panel. This monitoring is not of the actual current in the waveoff lights but rather of the actuating device. This is considered satisfactory, as the LSO can immediately see any lamp failure.

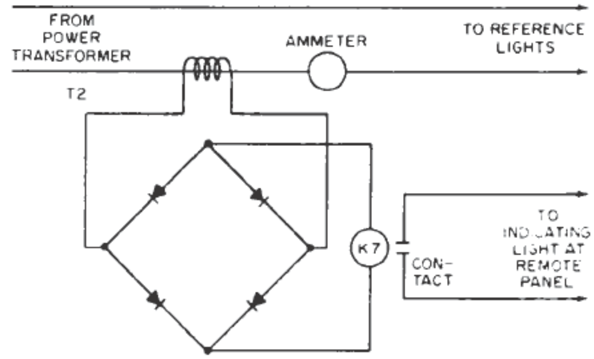

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Figure 15-19.—Monitoring circuit for reference light line.

The indicator lamp will flash in synchronism with the waveoff lights.

Cut Light Monitoring

The cut light operation is indicated on the remote control panels by a lamp. The lamp is energized by closing the cut light switch. Here again, the monitoring is of an actuating device and not the actual current. This is considered satisfactory as the lights themselves are easily seen by the LSO and lamp failure is readily detected.

TEMPERATURE REGULATION SYSTEM

Temperature regulation is used in the reference light enclosure and the lens enclosure. The reference lights require lamp cooling, while the lenses require constant temperature regulation.

Each stack of three reference lamps has an associated cooling fan (fig. 15-20), for limiting temperature rise in the vicinity of the lamps. The fans are 60-cycle axial exhaust fans. Free air passage between the five cells provides for partial circulation should any one of the fans fail.

Because temperature affects the focal length of the lenses, it is necessary to maintain a constant lens temperature. To accomplish this, the lenses are enclosed in an insulated box with the temperature controlled at 100° to 110° F. To maintain the desired temperature, heat from

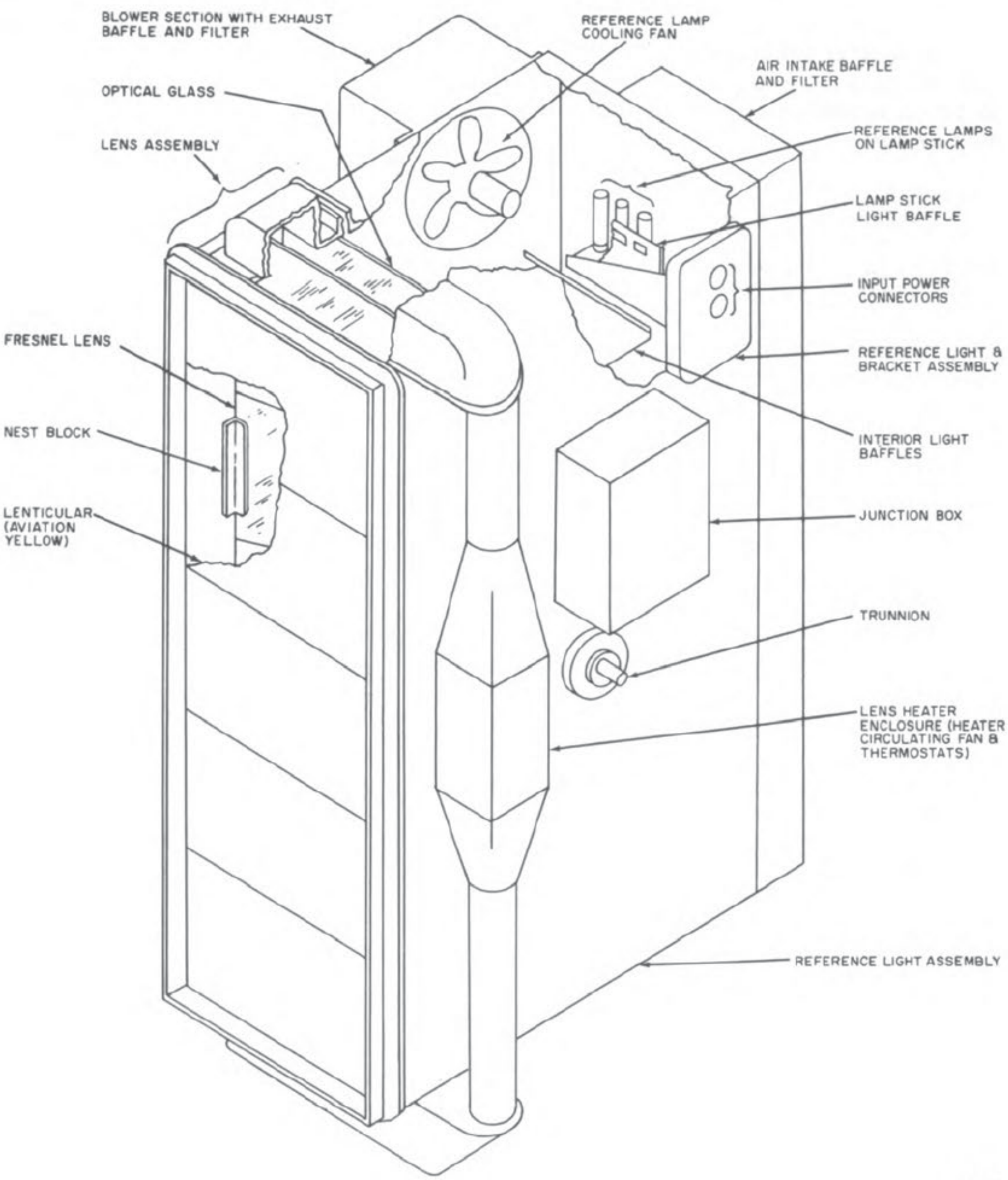

Figure 15-20.—Source light and lens assembly.

a thermostatically controlled tubular heater is circulated through the lens enclosure. This circulation is created by a 60-cycle axial fan that operates whenever the control circuit is energized.

Another thermostat is installed to monitor the heating system operation. This thermostat is set at the lowest acceptable operating temperature (approximately 100° F). Therefore, this thermostat will operate as long as the heating system is functioning properly. It will not go on and off as will the heater thermostat. The monitor thermostat operates an indicator lamp on the power panel. For normal operation, the light remains on.

ADJUSTMENTS AND TESTS

The adjustments and tests for the Fresnel Lens Optical Landing System will be considered under two broad headings—lighting system and stabilization system.

LIGHTING SYSTEM

The dimmer control rheostats set the voltage input to the control circuit of the dimmers for the various brightness steps. These rheostats may be adjusted by the step-by-step procedure given in the adjustment and test section of the associated optical lens landing system technical manual. A sample of this information is shown in table 15-1.

The adjustment procedure requires that the power panel be energized while some of its covers are removed, therefore, extreme care should be taken when making these adjustments. It is also recommended that the lowest appropriate full scale setting for the voltmeter be used for each setting to give maximum accuracy.

Operating Thermostats

The operating thermostats in the lens heating system are set to maintain the mean temperature in the vicinity of the center lens equal to approximately 110° F.

To determine if any adjustment is necessary, several thermostatic switching cycles should be observed after the warmup period. If the minimum temperature during the cycle does not fall below 105° F, and the maximum does not exceed 120° F, the operating thermostat is functioning properly. If it is found that these limits are exceeded, an adjustment of the thermostat adjusting screw can be made to correct the fault.

The monitoring thermostats in the lens heating system are adjusted to turn off the temperature ready lights if the lens temperature falls below an acceptable limit (95° F). If the thermostat needs adjusting, follow the procedure as outlined in the associated technical manual.

STABILIZATION SYSTEM

The various parts of the stabilization system are precisely adjusted at the factory. However, some final adjustments are necessary to match the system to a particular ship on which it is installed. All installation tests and adjustments are covered in detail in the technical manual, so will not be covered here. Remember that the tests and adjustments should be checked whenever the equipment is damaged or a component fails and is replaced. Occasionally slippages occur because of unusual or severe vibrations in the vicinity of rotating or sliding parts. Should this happen, adjustments and tests must be made.

Roll and Pitch Servos

If the system is not stabilized, a possible trouble source is a defective synchro. The synchros can be checked by testing for a short in the windings and by checking the voltage output.

Defective Motors and Tachometers

As in a synchro, faulty windings in a servo indicate a defective motor. A motor that is not

Table 15-1.—Reference Lights Dimmer Control Rheostat Adjustments

Brightness selector position	A-c voltmeter lead terminal point numbers	Rheostat to adjust	Voltmeter reading (volts)
Step 1	Determine for local installation	R24	11.1
2		R20	13.8
3		R16	17.7
4		R12	22.7
5		R8	30.0
6		R4	42.0

operating properly should be checked not only for a shorted or grounded winding but for faulty bearings as well.

A defective tachometer may be recognized by a lack of servo stability; however, all circuits having to do with stability should be checked before removing the tachometer. Should it be necessary to replace the tachometer, remember to adjust the antibacklash gear-set so that looseness in the gear train is at a minimum. This should not be achieved at the expense of too tight a mechanical fit since it reflects additional load on the motor and adds to the servo error.

Limit Stops

Cam actuated microswitches remove power from the servomotors before braking is applied by the mechanical stop.

When the servos are on electrical zero, each set of cams should be set so that the electrical switch is depressed about one-quarter of a shaft turn before the mechanical limit is reached. The cams should also be set in relation to each other so that only one electrical switch is depressed at any given time. Always keep an adjustment of left and right cams so that the override between the shutoff of power and the mechanical limit in one direction does not cause the other electrical limit to be depressed at the same time. Should this happen, servo instability and failure to recover properly will result. If it becomes necessary to replace a switch, be sure that the cam depresses the switch's lever sufficiently to break contact.

PREVENTIVE MAINTENANCE

The information given in this section is intended to aid the technician in maintaining and servicing the Fresnel Lens Optical Landing System Mk 0 Mod 0. It includes routine inspection, tests, lubrication, cleaning, and adjustments which should be performed periodically and regularly to maintain the efficiency of the system and to minimize damage caused by component failure.

REQUIRED MAINTENANCE EQUIPMENT

Table 15-2 lists recommended equipment for making the various tests and adjustments associated with maintenance.

PREVENTIVE MAINTENANCE PROCEDURE

Table 15-3 is made up of a list of recommended inspections, tests, lubrications, and cleanings associated with preventive maintenance.

CORRECTIVE MAINTENANCE

The I. C. Electrician responsible for the Fresnel Landing system will be expected to give the system the best service possible. When trouble develops, it will be his job to find it quickly and to repair it.

An important step in performing corrective maintenance is to determine the symptoms. No hasty decisions or random checking should be made by the I. C. Electrician. Rather, a logical deduction should be made based on step-by-step procedures which include measurement of voltage, resistance, and waveform checks.

Briefly, the trouble should first be localized to a single unit; and next, the faulty circuit should be isolated within that unit; then the defective part should be located within the faulty circuit.

Remember that efficient troubleshooting must be methodical and that haphazard testing wastes time.

THEORY OF LOCALIZATION

The most important point to remember in localizing trouble to a particular unit is to apply common sense. For example, if operation is normal at all units except for the roll servo, then the trouble is either in that particular unit or in the circuits that feed only that unit. If operation of all the units is abnormal, the cause of the trouble is probably in the circuits common to all the units.

Time can be saved by first deciding what circuit function is at fault; for example, 400-cycle 115-volt a-c power; 60-cycle 115-volt a-c power; stabilizer signal; or CT control signal. Once the faulty function is identified, running it down to a particular unit or component is usually simple, although sometimes quite tedious. Because blown fuse indicators can also fail, fuses should be checked before making extensive repairs.

Table 15-2.—Maintenance Equipment

Equipment	Quantity	Type
A-c vacuum tube voltmeter	2	Ballantine No. 643 or equivalent
Multimeter (V.O.M.)	1	Simpson No. 260 or equivalent
Clamp-on multimeter	1	Triplett No. 310-10 or equivalent
Assorted handtools	—	—
Dial thermometers (min. range 50-150°F)	3	Weston-type 2261

Table 15-3.—Preventive Maintenance Procedure

Item	Interval
CHECK	
General finish for cracks, peeling or rust. Refinish as required.	Semi-annual
Lenticular outside surface for scratches, dirt or warping. Clean or replace as required.	Monthly
Cables and wiring for breakage, wear, burning and loose terminals. Replace and tighten as required.	Monthly
Circuit Breakers for overheating and loose connections.	Semi-annual
Miscellaneous electrical components for overheating, swelling, discoloration, broken or loose terminal connections, binding. Replace or repair as required.	Monthly
Gearing for noisy operation and binding. Adjust or replace as required.	Monthly
Servo motors, tachometers, synchros and limit switches for signs of overheating or noisy operation. Replace.	Monthly
Panel lamps for burned-out bulbs. Replace.	Monthly
Reference lights current is not greater than 13.5 amps. Replace reference lights.	Weekly
Reference light fans for operation. This can be by holding hand near water baffle on outboard side of reference light assembly opposite each cell-checking air passage. Replace.	Weekly
Air baffles and filters for excessive dirt. Clean.	Semi-annual
Meters for broken or dirty windows. Replace or clean as required.	Monthly
Electrical contacts on all contactors, relays, and switches (where these contacts are exposed) for burning, pitting, dirt. Clean or replace where required.	Monthly
Trunnions and pillow blocks for excessive wear and binding. Lubricate with SAE 50 oil.	Semi-annual
All equipment for accumulation of dust and dirt (particularly terminal boards). Clean.	Semi-annual
Panel lights control rheostat-brush and track. Clean.	Monthly
Par 56 lamps and filters on datum, waveoff, and cut light assemblies for dirt and cracks. Clean or replace as required.	Monthly

UNIT TROUBLESHOOTING

As previously mentioned, failure of a system must always be traced to the responsible unit. The problem then is to track down the faulty component of that unit. Troubleshooting charts are available and can be used with servicing block diagrams (fig. 15-21) to help locate the trouble quickly. The unit troubleshooting charts will help to locate the fault after it has been localized to a unit.

These charts do not cover every conceivable equipment failure. However, by adhering to the general method of approach outlined in the charts, and by referring to applicable schematic diagrams and circuits, the more probable troubles can be readily isolated and remedied.

Care must be used to follow the correct sequence of tracing. Troubleshooting must proceed in an orderly fashion as outlined in the charts since each step is directly dependent upon the preceding step. Do not attempt to proceed to another unit or circuit until the one under consideration is shown to be normal. As mentioned before, do not attempt to isolate a circuit trouble by haphazard guessing or "shots in the dark."

STABLE ELEMENT CHECK

Lack of stabilization is evident when the ship is rolling but the lens box assembly tilt does not change. A possible cause, and one which should be investigated first, is that roll and pitch signals are not being received by the Fresnel system from the gyro.

The stable element signals are applied to the appropriate control transformer stators and are of varying amplitude. To determine if the signals are being received, measure the voltages of the 2-speed and 36-speed control transformer stator windings. The stator windings S1-S2, S2-S3, S1-S3 should vary the 2-speed and the 36-speed control transformers over a range of from zero to 57.5 volts. At least two of the three measurements for each speed must not be zero.

If there is a varying voltage at the control transformers, the fault is not the lack of a stable element signal. The trouble must be in the Fresnel system itself.

EXAMPLE OF LOCATING A FAULT

Assume that word is received from the landing signal officer that the Fresnel system has pitch stabilization but no roll stabilization. Once it is known that trouble exists, the next step is to acquire all possible information.

The landing signal officer at the deck edge unit is one of the best sources of information. Find out what symptoms the LSO has observed and also what, if any, checks already have been made. Then check the system for the proper set up—power breakers closed, selector switches on proper position, and so forth. If the LSO has not checked the operation of the other deck edge units, then this should be done. If the roll stabilizing system is working on these units, that eliminates the ship's stable element as being at fault, for its signal is common to all three systems. In fact, the 2-speed and 36-speed CTs, the roll servo tachometer, the roll magnetic preamplifier and power amplifier, the roll servo motor, and the roll limit switch, can all be eliminated for their circuits are also common to all three deck edge units.

Note that up to this point, no tools have been used. To complete the electrical check on the deck edge unit concerned, test the operating voltage at the servo motor. If operating voltage is present, the trouble is in the mechanical gearing system. Check the gearing for sheared pins, broken gears and shafts, and locked trains. The trouble should be found in the gear system.

Space does not permit going into all the possible defects, but a step-by-step procedure has been outlined that can be used in most troubleshooting where there are many components to the system.

The important point to remember is to get all possible information from the system operator at once. Then make a check on the setup of the system to be sure that it is set for the desired operation. Next, by using common sense and deductive reasoning, isolate the trouble, as far as possible, to specific units before actually opening up the equipment.

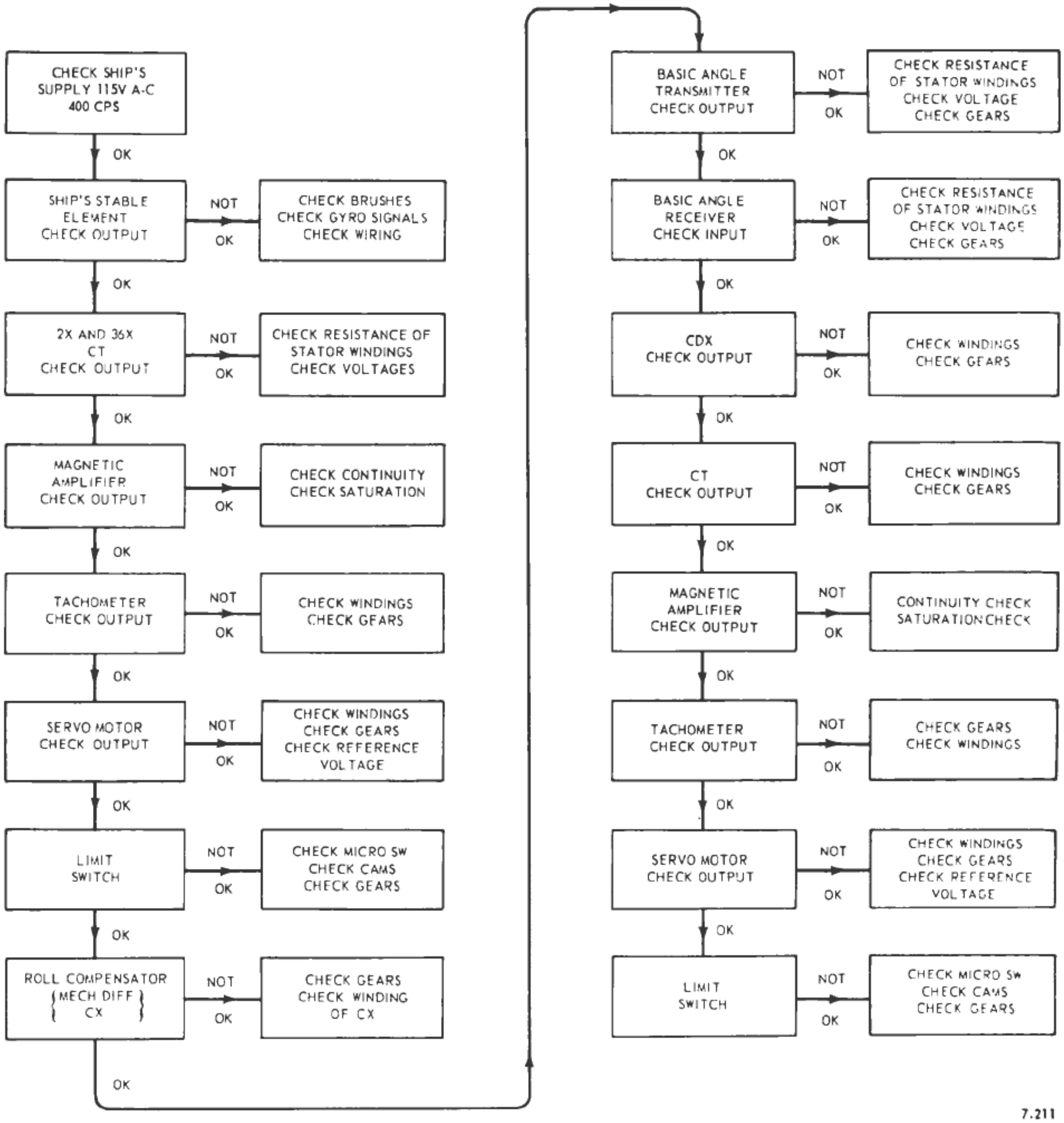

Figure 15-21.—Block diagram of stabilizing system troubleshooting chart.

QUIZ

1. What is the purpose of the stabilization system?
2. Where does the roll signal originate?
3. What is the load for Z1?
4. What component produces a feedback signal to Z1 for stabilization?
5. What is the output of the CDX?
6. The crossover network mixes what two signals?
7. When is the 36-speed signal most effective?
8. In what direction does B1 drive the 2-speed and 36-speed CTs?
9. What is the purpose of the roll servo limit switch?
10. How is B1 shaft rotation converted to roll correction?
11. What two components make up the basic angle receiver?
12. What actually positions the reference light?
13. What controls K1?
14. What happens when S1 of the limit switch moves to position 2?
15. What does the error indicating circuit do?
16. What is the power for the light system?
17. How is the brightness of the lighting system controlled?
18. What is the purpose of the panel selector switch?
19. On step 7 of the brightness switch, how are the lights connected?
20. What type of transformers are used for the datum lights?
21. What are the two purposes of the reference light transformers?
22. At what voltage are the reference lights rated?
23. What happens when the brightness switch is placed on step 7?
24. In a waveoff situation, what switch starts the pulsator rotor?
25. What is the relation of the waveoff lights to the reference light during waveoff?
26. How is monitoring accomplished in this system?
27. How are the reference lights monitored against lamp failure?
28. Is the actual current in the waveoff lights monitored?
29. Why is it important to keep the lenses at a constant temperature?
30. What sets the voltage input to the control circuits of the dimmers on steps 1 through 6?
31. What precaution should be taken before adjusting the dimmer rheostats?
32. What might cause the stabilizing system to become saturable?
33. What component may cause instability in the servo system?
34. What would be the effect of both limit switches being depressed at the same time?
35. How should troubleshooting be approached?
36. In a faulty system, what circuits should the IC2 try to eliminate first as a source of trouble?

APPENDIX 1

ANSWERS TO QUIZZES

Chapter 1

NEW CHALLENGES

1. Manual of Qualifications for Advancement in Rating, NavPers 18068 (Revised).
2. To reflect organizational and procedural changes that affect the rating structure.
3. To include additional changes that may have occurred since the publication of this training course.
4. (1) General, (2) service, and (3) emergency ratings.
5. The general rating.
6. (1) Practical factors, and (2) knowledge factors.
7. (1) Proficiencies in the practical factors are tested by on-the-job demonstration with materials, tools, and equipment; (2) knowledges of the examination subjects are tested by a written examination.
8. Record of Practical Factors, NavPers 760.
9. As a standard checkoff list of all the practical factors required to be demonstrated in each rate as a prerequisite for advancement.
10. Pay grades E-3 through E-6.
11. To provide supplementary study material.

Chapter 2

ENGINEERING MATERIAL

1. Operating and maintenance material consumed in use.
2. Material of a nonconsumable nature.
3. A replacement part of a piece of machinery or equipment.
4. Federal Supply Classification system.
5. (a) Eleven digits, and (b) in groups of 4, 3, and 4, separated by hyphens.
6. (a) The group, and (b) the class.
7. (a) The Federal Item Identification Number, and (b) the FIIN identifies a specific item within a group and class.
8. (a) Cognizance symbol, and (b) the bureau, office, or SDCP that exercises control over the material.
9. To specify the amounts of onboard equipage and repair parts a ship is required to carry.
10. The Shipboard Allowance List (SAL) and the Coordinated Shipboard Allowance List (COSAL).
11. The SAL covers hull, machinery, and electrical material only, and the COSAL also includes electronic and ordnance material.
12. The SAL becomes a COSAL.
13. Introduction, equipment index (part I), allowance parts list (part II), and stock number sequence list (part III).
14. (a) Section A, and (b) section B.
15. The component identification number.
16. Complete component characteristic data and breakdown (name, description, and number) of the repair parts.
17. The final authorized onboard allowance quantity and other components that use the same part.
18. Bureau of Ships repair parts, general stores material, and Bureau of Ships material not carried in stock.
19. Ship's assemblies and repair parts, and submarine assemblies and repair parts.
20. Inventory control and technical control, respectively.
21. Issue refers to expenditures of material from the custody of the supply department to shipboard use.

22. Request For Issue or Turn-In (DD Form 1150).
23. When the repair part is removed from the repair parts box or bin for installation in the parent equipment.
24. Request For Repair Parts (SandA Form 302).
25. To determine if a suitable substitute can be found in general stores.
26. Enter the standard Navy stock number opposite the item in the allowance list with notation "Storeroom Stock."
27. The head of department responsible for the use of that equipage.
28. The supply officer.
29. Near the machinery for which the repair parts pertain.
30. According to the group index number of the material on the allowance list and the page number on which the repair parts are listed.
31. By stock number, manufacturer's part number, or allowance list group, page, and line number.
32. Material for which an individual stock record card is maintained on each item.
33. Equipage Stock Card and Custody Record (SandA Form 306 or 460).
34. Stock Control Record (SandA Form 489 or 489A).
35. Opposite each page of the Bureau of Ships allowance list on which repair parts appear.
36. To record usage, replenishment, and locator data for the ship's repair part appearing on the opposite (page) Bureau of Ships allowance list.
37. As the commanding officer directs or at least once during the fiscal year.
38. A commissioned officer or a board of three officers, one of whom and as many as practicable will be commissioned officers.
39. Head of department having custody of material being surveyed.
40. In all cases when a formal survey is not required or directed by the commanding officer.
41. A Survey Request, Report, and Expenditure (SandA Form 154).
42. Forwarded to the supply department for preparing a smooth survey request.
43. Determines whether a formal or an informal survey is appropriate.
44. Inspects the material being surveyed to determine its condition, or if missing, to fix the cause and responsibility of the loss in order to make a specific recommendation for its disposition.
45. Approves or disapproves the recommendations for the disposition of the material being surveyed.

Chapter 3

PRINCIPLES AND ASPECTS OF SOUND AND SOUND SYSTEMS

1. A state of vibration.
2. Transverse and longitudinal.
3. At right angles to the direction of propagation.
4. Forward and backward in the direction of propagation.
5. Because gases and liquids offer only elastic resistance to compression and no sustained resistance to shear or change in shape.
6. The disturbance resulting from the vibrating motion of the tines moves outward through the medium in the form of a progressive longitudinal wave consisting of alternate compressions and rarefactions.
7. The time in seconds required for the particle to complete one vibration.
8. The number of vibrations completed per second.
9. The maximum displacement of the particle from the undisturbed, or equilibrium, position.
10. When they are vibrating with the same frequency and continually pass through corresponding points of their paths at the same time.
11. When they reach their maximum displacements in opposite directions at the same time.
12. The distance measured along the direction of propagation between two corresponding points of equal intensity that are in-phase on adjacent waves.

13. Elasticity, density, and temperature.
14. Pitch, intensity, and quality.
15. The vibration frequency of the sounding source.
16. The amplitude of vibrations.
17. Fundamental tone.
18. The number and frequency of the overtones and their relative intensity with respect to the fundamental.
19. The wave is reflected at the boundary surface.
20. The wave undergoes an abrupt change in direction, which is known as refraction.
21. Additive interference.
22. Subtractive interference.
23. Beat frequency, or difference frequency.
24. Beat frequency produces alternately loud and soft pulses or throbs.
25. Resonance.
26. Doppler effect.
27. Acoustics.
28. An echo.
29. Reverberation.
30. The decibel.
31. The least sound perceptible to the ear.
32. Frequency distortion.
33. Nonlinear distortion.
34. By employing a suitable impedance matching transformer between the generator and the load.
35. In the constant voltage system, the loudspeakers or loudspeaker groups can be added or subtracted at will without requiring any system adjustment or necessitating any balancing or loading resistors.
36. The resistance of the conductors and the distributed capacitance between the conductors of the transmission line.
37. High line loss and less power available to drive the loudspeaker.
38. The capacitive reactance of the distributed capacity between the conductors will approach the line impedance at higher frequencies, resulting in a shunting effect across the loudspeaker load to reduce the voltage available at the loudspeaker.
39. The wires connecting the microphones to the input of the amplifier.
40. Extraneous voltages will be introduced into the input circuit of the amplifier where they will be superimposed on and amplified with the normal input signal, and will appear in the output as noise.
41. Magnetic pickup, static pickup, and longitudinal currents.
42. Acoustical feedback.

Chapter 4

MICROPHONES AND LOUDSPEAKERS

1. To convert sound energy into electrical energy.
2. Magnetic and dynamic.
3. A permanent magnet and a coil of wire inside of which is a small moving armature that is coupled to the diaphragm by means of a drive rod.
4. A coil of wire attached to a diaphragm and a radial magnetic field in which the coil is free to vibrate.
5. A continuity check at the plug terminals and the d-c resistance of the microphone element coil.
6. Frequency response, impedance, and sensitivity.
7. By cutting off the system response at some lower limit and by employing an emphasized frequency-response characteristic that rises with increasing frequency.
8. Only as it relates to the load impedance into which the microphone is designed to operate.
9. Because a more sensitive microphone requires less amplifier gain, thus providing a greater margin over thermal noise, amplifier hum, and noise pickup in the line between the microphone and the amplifier.
10. The frequency limits within which good amplifier performance can be expected.
11. By frequency response characteristic, which is a curve amplifier gain versus frequency.
12. The difference (expressed in decibels) between the volume level of a signal at the input of the amplifier and the volume level of the same signal at the output of the amplifier.

13. Only when the amplifier is used with the correct terminating impedance.
14. The maximum single frequency power that the amplifier can deliver to a resistance load without overloading.
15. Linear.
16. To increase the intelligibility of speech under conditions of high background noise.
17. By introducing a circuit in the amplifier that varies the gain of the system as a function of the input level.
18. The effective amplifier gain will be lowered and the frequency-response characteristic may be altered.
19. Maximum power output with a minimum of distortion cannot be obtained.
20. To convert electrical energy into equivalent sound energy and to radiate this energy into the air in the form of sound waves.
21. Direct radiator type and horn type.
22. Dynamic, or moving-coil, driving mechanism.
23. The operation is the reverse of that of the dynamic microphone.
24. To prevent the back wave from neutralizing the front wave at low frequencies.
25. A baffle.
26. Straight and folded horns.
27. By coupling individual horn sections combined mechanically into a common loudspeaker assembly.
28. The frequency response of the loudspeaker.
29. The frequency and the size of the horn mouth.
30. As the frequency increases the directivity increases.
31. Heating, mechanical strength, and production of nonlinear distortion.
32. By matching transformers.

Chapter 5

ANNOUNCING AND INTERCOMMUNICATING SYSTEMS

1. To transmit orders and information between stations within the ship by means of amplified voice communication.
2. (1) Central amplifier system, and (2) intercommunicating system.
3. The central amplifier system and the intercommunicating system are employed when it is desired to (1) broadcast orders and information simultaneously to a number of stations, and (2) provide two-way transmission of orders or information respectively.
4. Voice communications, and alarm signals.
5. (1) Collision alarm; (2) chemical attack alarm; (3) general alarm; and (4) sonar alarm signals.
6. Alarm signals are transmitted only over the 1MC loudspeakers.
7. The 1MC-6MC control station.
8. Circuit 1MC has priority control over all microphone control stations.
9. To generate the alarm signals.
10. To increase the microphone output on voice signals to a level sufficiently high to drive the power amplifiers.
11. To increase the level of the alarm signals from one of the oscillators and the voice signals from one of the preamplifiers for reproduction by the loudspeakers.
12. Two.
13. To develop the normal input signal for push-pull operation.
14. The signal is applied to the grids of V11A and V12A through series resistor R37, C14, and C13.
15. Resistance coupled through C11 and R31 to the control grids of V9A and V10A.
16. Resistance coupled through C12 and R32 to the control grids of V9B and V10B.
17. A rise in the negative voltage existing between the plates of V7 and V8 and ground.
18. (a) The grids (pins 1 and 7) of V1 and V2; (b) to control the gain of this amplifier stage.
19. Rectifier tubes V7 and V8 conduct at a lower signal level and thus take control of the preamplifier gain at a lower signal level.
20. Resistance coupled to the grids of driver tubes V17B and V18B through R60.

21. To supply inverse feedback voltage to the cathodes of the voltage amplifier stage V15A and V16A to reduce the effect of changing load conditions on the output voltage.
22. V35B and V36B produce a 1,000 cps signal.
23. The output of V35B and V36B is fed through C57, R106, R105, R101, and C52 to the grids of V33 and V34 for amplification.
24. To pulse the 1,000 cps signal of the oscillator and produce the collision alarm.
25. Relay K105 actuates to remove ground from the grid resistor R102 and to apply cut-off bias from R145 in the power supply.
26. By the time constant of R103 and C53.
27. From the driver stage V35A and V36A and the power amplifier V37 and V38.
28. (a) Relay K104 applies plate voltage to the 600 cps phase-shift oscillator V31B and V32B; and (b) energizes relay K103 which applies plate voltage to the 1,500 cps phase-shift oscillator V31A and V32A.
29. Relay K108 applies plate voltage to V29A and V30A.
30. It causes V31A-V32A and V31B-V32B to conduct on alternate half cycles and to generate a jump tone signal alternating between 600 and 1,500 cps at 1 1/2 cycles per second.
31. Circuit 1MC amplifier is in use.
32. Circuit 6MC amplifier is in use and will have no effect on circuit 1MC operation.
33. Circuit 1MC is in use but circuit 6MC can be selected and used at the same time without interference to the transmission on circuit 1MC.
34. The busy 1 and busy 2 indicators are lighted at all microphone control stations and the alarm signal is transmitted to all circuit 1MC loudspeakers.
35. Operate the microphone station disconnect switches to the OFF positions on the audio amplifier one at a time until the defective microphone control station is isolated.
36. Operate the loudspeaker group disconnect switches to the OFF position on the audio amplifier cabinet one at a time until the defective loudspeaker group is isolated.
37. (a) From the oscillator not in active service; and (b) operating the test chemical attack alarm switch to the ON position.
38. Rotating meter switch S2 to positions 1 through 7 inclusive connects the output meter M1 to terminals in the various output stages of the preamplifier.
39. (a) From the oscillator not in active service to drive the preamplifier not in active service which in turn drive the power amplifier not in active service; and (b) by operating the test start switch on the amplifier cabinet to the ON position.
40. Rotating meter switch S3 to positions 1 through 7 inclusive connects the output meter M2 to terminals in the various stages of the power amplifier.
41. Switching meter M3 into each stage by meter switch S4 and operating the various test alarm switches.
42. One type can originate calls to 10 other stations and the other type can originate calls to 20 other stations.
43. (1) Reproducer, (2) controls, and (3) amplifier.
44. (1) It serves as a microphone to transmit sound from the unit to other units in the system; and (2) as a loudspeaker to reproduce sound transmitted to the unit by any other unit.
45. The amplifier of the calling unit.
46. Selects the function of the reproducer.
47. When the station selector pushbutton is depressed to call another station and the station being called is busy.
48. The volume of the incoming signal only.
49. To switch the primary of T1 to either the internal loudspeaker LS1, used as a microphone, or to an external microphone over a frequency network.
50. As a line transformer.
51. From T2-14 through contacts 4-3 of relay K2, through contacts 4-3 of the upper switch assembly S2U, to terminal 2C of station 1, and to line MC2C.
52. From T2-14 through contacts 2-1 of relay K2, through contacts 6-5 of the upper switch assembly S2U, to terminal 2, and to the line MC2.
53. The signal goes from the volume control S25 through contacts 1-2 of the press-to-talk switch S26, through the loudspeaker LS, through contacts 5-4 of the press-to-talk switch S26, through terminals Y4-Y3, through contacts 5-6 of talk relay K1, to terminal Y2, over line MC3Y21 to terminal Y1, and to T2-7 of station 3A.

54. The input to the audio circuit will be open for both stations.
55. Indicator lamp I201 will light with full intensity.

Chapter 6
SUPPLEMENTARY COMMUNICATION EQUIPMENT

1. To amplify incoming speech to such a level that the reproduced message will be clear and understandable aboard ship where the noise level is high.
2. (a) One amplifier, (b) one to six headsets, and (c) one or two loudspeakers.
3. By the volume control S1 in the signal circuit between T1 and V1A.
4. When the on-off power switch S2 is in the OFF position.
5. Through wafer 2 contacts 1-3 and 4-6 of switch S2.
6. Relay K2 grounds the amplifier input at the secondary of T1 and deenergizes relay K1 which connects the telephone line to the secondary of T2 to bypass the amplifier.
7. (1) Resistance measurements, (2) voltage measurements, and (3) signal tracing.
8. (a) Terminals X and W, (b) ON position, and (c) position 6.
9. Within 10 percent of the readings listed in the manufacturer's technical manual.
10. Between ground (chassis) and the grid and plate of each tube.
11. (1) Issuing orders from the bridge to personnel at topside stations, (2) communicating between ships when fueling or taking on stores at sea, and (3) communicating to and from tugs while maneuvering and docking.
12. In parallel.
13. The volume control R2, when advanced, shorts out parts of R2A and R2B to reduce the resistance between the remote microphone and the grids of V1A and V1B.
14. Yes.
15. To centralize the control of voice communication circuits at key tactical stations in the ship.
16. To provide a secondary control point for the radiophone and the interphone circuits.
17. To control one radio transmitting or receiving circuit.
18. To select any one of the four transmitters or four receivers connected to the terminal units in the cabinet.
19. To supply 12-volt d-c power to operate the carbon microphones and relays and in the equipment.
20. The associated power-on indicator lamp 3I29 is lighted (red).
21. (a) The transmitter is being operated from another station and (b) the transmitter can be operated from the master console.
22. The operation of relay 3K4 which is energized when the radiophone handset talk switch is depressed.
23. Relay 3K4 energizes the master control relays (3K5, 3K6, 3K7, and 3K8) which operate simultaneously to apply +12-volt d-c power to the contacts of the associated pushbutton selector switch 3S32 (in this case) that is depressed.
24. Place the on-off power switch in the ON position and switch the circuit selector switch to the circuit to be monitored.
25. To select the time delay for playing back the recorded message of any one of five different recorder outputs.
26. Four radio channels.
27. To provide an independent telephone system between the master console and the subconsoles.
28. Disconnects the call light circuit to extinguish 4I1 and 3I48 and to open 4S11 which in turn opens the buzzer circuit and silence buzzer 4E1.
29. (a) The called intercom station is busy, and (b) the called intercom station is not busy.
30. The call lamp 3I89 at the calling station flashes intermittently.
31. The call lamp 3I89 will be lighted (amber) steadily.
32. (1) Relay 3K11 in console 2 opens the AUDIO IN circuit to its intercom loudspeaker 3LS3 to prevent acoustic feedback, and (2) connects its IN USE lamp 3I17 through R175 to the 10-volt a-c LO power causing the lamp to flash through the BUSY OUT line.

33. To provide a means of communication between the master console and the ship's sound-powered telephone system.
34. The incoming telephone signal passes through the isolating resistors 3R38 and 3R39 to the input of the monitor amplifier where it is amplified and applied to the loudspeaker 3LS1 through the volume control 3S23.
35. The incoming telephone signal passes through isolating resistors 3R24 and 3R25, through normally closed contacts of relays 3K2 and 3K1 to the input of the handset amplifier where it is amplified and fed through normally closed contacts of relay 3K3, resistors 3R1 and 3R2, and the handset volume control to the handset receiver.
36. All sound-powered telephone circuits connected to the talk-off-mon selector switches that are in the TALK position.
37. The incoming paralleled signals pass through the isolating resistors 3R82 and 3R83 to the input of the monitor amplifier where they are amplified and applied to the sound-powered telephone loudspeaker 3LS1 through the speaker volume control 3S23.
38. The incoming paralleled signals pass through the isolating resistors 3R66 and 3R67, through normally closed contacts of relays 3K2 and 3K1 to the input of the handset amplifier where they are amplified and fed through normally closed contacts of relay 3K3, the resistors 3R1 and 3R2 and the handset volume control 3R18 to the handset receiver.
39. (1) Sound-powered telephone monitor, (2) sound-powered telephone handset, (3) radiophone-receiver, (4) radiophone-microphone, and (5) intercom amplifiers.
40. (a) The selected channel can be operated from the subconsole, and (b) the selected circuit is in operation from another station.
41. (1) Connects the handset receiver through the handset volume control 4R1 and the radiophone selector switch 4S14 to the radio-receiver line of the selected circuit, and (2) connects the coil of relay 4K1 to the handset talk switch.
42. Four radio terminal units and a channel selector unit.
43. To permit control of the associated transmitter and receiver from the master console or the subconsoles, or from the terminal unit itself.
44. (1) Circuit selector switch 6S1, (2) telephone-type dial 6S2, and (3) synchro indicator M1.
45. (a) At the master console and the subconsoles, and (b) at the terminal unit.
46. (a) Power is applied to the transmitter, and (b) the transmitter is on the air.
47. Relay 5K2 operates but has no affect because all the circuits to the master console and subconsoles are inoperative with switch 5S1 in the LOCAL position.

Chapter 7

SOUND RECORDING AND REPRODUCING SYSTEMS

1. Mechanical, photographic, and magnetic.
2. Disk, film, tape, and wire.
3. Engraving and embossing.
4. (a) Engraved on disks, and (b) embossed on disks or films.
5. Microphone, audio amplifier, recording head, stylus, and recording medium.
6. The stylus swings from side to side to cut or deform the sound pattern on the walls of the groove.
7. (a) Frequency, and (b) amplitude of the lateral swings.
8. Variable density and variable area.
9. Receives the amplified electrical signals from the amplifier and orients the magnetic particles in the tape or wire according to the signal pattern.
10. The same.
11. To obtain a substantially linear relationship between the flux density in the recording medium and the magnetizing force.

12. By applying a h-f a-c signal to a special erase head, which disorients the magnetic particles in a previously recorded tape or wire.
13. Recorder-reproducer assembly, amplifier assembly, and remote control unit.
14. Tape-drive components, rewind and takeup components, head assembly, and control box.
15. By overcoming a difference in torque obtained by operating one (rewind or takeup) motor at full torque and the other at reduced torque, depending on the mode of operation.
16. By brakes provided on the rewind and takeup motors.
17. Erase, record, and reproduce heads.
18. Record, reproduce, and power supply subassemblies.
19. Channel A amplifier, channel B amplifier, AVC circuit for channel B, bias oscillator, and record level indicator.
20. Inputs of 150-ohm microphone, 200,000-ohm balanced bridging line, and 600-ohm balanced line.
21. Inputs of 30,000-ohm balanced bridging line and 600-ohm balanced line.
22. Potentiometer R37 across the secondary of T3 in the channel B amplifier (fig. 7-11).
23. The adjusted voltage from R37 across T3 (fig. 7-11) is amplified by V8B and fed to the grid of the cathode follower, V8A, and the output of V8A supplies the signal voltage to detector stage V7; the rectified AVC voltage developed across R45 is filtered by C30, and applied to the grids of V4 and V5 through R29A and R29B, respectively.
24. By applying a positive bias voltage to the cathode of the detector stage, V7 (fig. 7-11).
25. Through C1 and R1 (channel A) and through C2 and R2 (channel B).
26. Potentiometer R21 for channel A and potentiometer R38 for channel B (fig. 7-11).
27. To select the channel to be visually monitored by the record level indicator.
28. (a) Half-wave rectifier V24, and (b) full-wave rectifier V25.
29. C45 and R78 through contacts 4-5 of relay K9.
30. Rectifier CR1.
31. To filter the -600 volt direct current supplied to the grids of V10.
32. To filter the voltage supplied to the plates of all the other tubes in the amplifiers.
33. (a) Power transformer T6, and (b) capstan drive motor B3 through S2 and rectifier CR1.
34. To select the channel on which the record level is to be set.
35. To start and stop the recording process.
36. That power is applied and that the tape is threaded at the recorder-reproducer set.
37. That the equipment has been placed in the record mode either at the remote control unit or at the recorder-reproducer set.
38. (a) No; (b) because the two switches are in parallel.
39. (a) Reproduce mode; (b) both channels.
40. (a) Deenergized; (b) C45 and R78 through contacts 4-5.
41. (a) Energized; (b) C45 and R77 through contacts 5-6.
42. Relay K1 remains energized by the discharge of C4A and C4B after S1 is placed in the NEUTRAL position to allow the tape to stop before tape motion starts again in response to S10 or S8, and avoid tape breakage.

Chapter 8

SOUND MOTION PICTURE SYSTEMS

1. The sun and stars.
2. The moon and planets.
3. Because of the high temperature of its filament.
4. Transverse.
5. The amplitude.
6. The wavelength.
7. The wavefront.
8. Light ray.
9. The velocity equals the frequency times the wavelength, $v = f\lambda$.
10. The frequency of vibration and the associated wavelength of the wave.

11. Because all colors are contained in sunlight and each object reflects that part of the spectrum associated with its own color.
12. Yes.
13. Incident ray.
14. Point of incidence.
15. Reflected ray.
16. Normal to the surface.
17. Angle of incidence.
18. Angle of reflection.
19. The angle of incidence equals the angle of reflection.
20. Refracted ray.
21. Principal focus.
22. Focal length.
23. The presentation on a screen of a series of images taken in very rapid succession by a motion picture camera.
24. 16 mm. film.
25. Series of instantaneous photographs of a moving subject, and record of the sound associated with the motion of the subject.
26. Because the sound track must pass the scanning beam when the picture is at the aperature.
27. As a continuous photographic image along a narrow strip at one side of the film called the sound track.
28. Variable area recording, variable density recording, and magnetic tape recording.
29. By zig-zag waves along the sound track.
30. By parallel lines that vary in spacing and intensity across the sound track.
31. Convex lens.
32. (a) Twice during each frame; (b) once while the film is moving forward and again while a frame is being held stationary in the projector.
33. Projection lamp, reflector, condenser lens, shutter, aperture, film gate, and projection lens.
34. Concentrates the light from the filament of the projection lamp on the film aperture.
35. Cuts off the light when required by a pull-down blade and an antiflicker blade.
36. Focuses the image of the film frame on the screen.
37. Exciter lamp, optical unit, photocell, and mirror.
38. Concentrates the light from the exciter lamp on the sound track.
39. Reflects the light that passes through the sound track to the anode of the photocell.
40. Corresponding variations are produced in the electron emission through the photocell.
41. The variations in electron emission are converted into voltage variations across a resistor and fed to an amplifier, the output of which is converted into audible sound waves at the loudspeaker.
42. Projector, internal amplifier, and internal loudspeaker.
43. Minimizes the r-f noise.
44. Controls simultaneously the sound and picture changeover from the outgoing projector to the incoming projector.
45. (a) Open position on outgoing projector, and (b) closed position on the incoming projector.
46. Developed across R8 and applied to the grid of V2A.
47. Blocks the d-c photocell bias.
48. Permits adjustment of the input signal to prevent overloading the amplifier and to ensure a 20 db gain reserve.
49. R17 in series with C17.
50. Controls the frequency response characteristics of the internal amplifier.
51. Applies negative feedback to V3A to improve stability and frequency response of the amplifier and at the same time reduces distortion.
52. Phase inverter V3B drives V4 from the plate circuit and V5 from the cathode circuit.
53. So that the thermal inertia of the lamp prevents the exciting current from modulating the output of the photocell, V1.
54. To move the a-c components of the resulting d-c voltage from rectifier tubes V7 and V8.
55. Supplies the positive bias voltage for the photocell V1 in the projector.
56. Provides for rapid switching between projectors to phonograph or microphone.
57. Prevents the 112,000-cycle signal developed by V15 from feeding back into the d-c power supply.
58. Supplies positive bias voltage for the photocells in both projectors.
59. Balance resistor R94, which simultaneously increases the voltage on one projector input, and decreases the voltage on the other projector.

60. (1) No one should sit outside an angle of 30 degrees from the center line (projection axis), (2) not closer to the screen than two screen widths, and (3) not farther from it than six screen widths.
61. At least 6 feet.
62. (1) Two direct radiators and two horn loudspeakers; (2) the direct radiators are mounted on the screen frame (one on each side) and tilted to cover the front half of the audience; the horn loudspeakers are mounted on top of the screen frame (one on each side) and tilted to cover the rear third of the audience.
63. Dual projection equipments utilizing external amplifiers.
64. By means of the bridging cable connected between the OUT bridging jack of the primary amplifier and the IN bridging jack of the secondary amplifier.
65. Secondary amplifier is a slave to the primary amplifier.
66. Dead spots and loss of sound intensity.
67. Echoes and reverberations.
68. Mount a number of loudspeakers at frequent intervals on the overhead facing directly downward.
69. The projector sound system consisting of the exciter lamp, photocell, and associated light path components.
70. Exciter lamp oscillator V6.
71. If a "plop" is not heard in the speaker after inserting a piece of cardboard between the sound drum and sound lens with no film in the projector and with the volume control in the MID position.
72. Internal amplifier or loudspeaker.
73. The lamp is defective or no filament power is present.
74. Move the output tube, V4 or V5, in and out of the socket with no film in the projector, the motor-lamp switch in the MOTOR position, and the volume control in the extreme clockwise position, noise from the loudspeaker indicates the tube and speaker are operating.
75. Rectifier tubes V7 and V8.

Chapter 9

DIAL TELEPHONE SYSTEM

1. Primarily an administrative circuit that provides complete selective telephone communication throughout the ship.
2. So that any two telephones in the system can be interconnected.
3. A dial.
4. It causes a serious of interruptions or impulses in the line current.
5. The digit dialed.
6. Telephone station equipment, automatic switchboard equipment, power equipment and accessory equipment.
7. Protected and exposed.
8. An extension signal.
9. The automatic switchboard.
10. Power control panel, motor-generator set or rectifier, and storage battery.
11. To establish calls to and from shore exchanges when the ship is in port, and between ships when they are nested.
12. (1) Linefinder, (2) selector, and (3) connector.
13. To find the line of the telephone seeking to make a call and to extend the line to the selector.
14. No.
15. To extend the line of the calling telephone to the connector.
16. By the first digit dialed at the calling telephone.
17. To extend the line of the calling telephone to the line of the called telephone.
18. By impulses transmitted from the dial of the calling telephone.
19. Line-and-cutoff relay.
20. The bell to which the selector is stepped.
21. The connector switch is actuated to step its wipers up and around to the set of contacts associated with the called telephone station.
22. The banks of the connector switches are multipled by interconnecting the respective sets of contacts in each of the banks.
23. A linefinder switch and a connector switch permanently connected to each other.

24. Fifteen finder-connector links.
25. The conductors from the connector line bank to the line of a telephone.
26. Only as many as there are finder-connector links.
27. The group relays release to normal in preparation for actuating the next finder and the distributor selects the next idle finder to have it ready for the next incoming call.
28. The line-and-cutoff relay operates the remainder of its contact springs to cut off its own winding from the line.
29. A linefinder and a selector permanently connected to each other.
30. (1) Chooses the proper group of connectors, and (2) hunts for an idle connector in that group.
31. A maximum of 60 simultaneous conversations.
32. The selector steps up to the proper level and then steps around to hunt for an idle connector trunk.
33. Transmitter, receiver, dial, and ringer.
34. Staterooms, cabins, offices, and similar stations.
35. All stations except those on weather decks, and those designated as type A stations.
36. In stations on weather decks and other stations exposed to moisture.
37. Transmitter and receiver.
38. Dial, hook switch, ringer, two capacitors, and induction coil.
39. To intermittently open and close the impulse springs during the time the dial mechanism is returning to normal.
40. To extend the connection to the line associated with the dialed number.
41. To allow the relays in the Strowger switches to operate properly between each series of impulses.
42. The receiver is shunted.
43. (a) Placed on; (b) removed from.
44. Because it will operate over a wide range of frequencies.
45. To pass a-c and block d-c through the ringer.
46. To improve the transmission output characteristics of the telephone.
47. Increases the output volume and decreases sidetone.
48. Ringing, dialing, transmission, and receiving circuits.
49. The ringing circuit.
50. The dialing circuit.
51. The main talking circuit.
52. The local talking circuit.
53. Aids.
54. Antisidetone.
55. (a) Main receiving circuit; (b) local receiving circuit.
56. (a) Two conductors; (b) designated L1 and L2.
57. (a) Across the line; (b) metallic ring.
58. (a) Three conductors; (b) designated L1, L2, and G.
59. Ground ring.
60. By connecting, at the line-and-cord terminal block, the red-coded and white-coded wires to terminal L2 and the black-coded wire to terminal L1.
61. By connecting, at the line-and-cord terminal block, the black-coded line wire to terminal L1, the white-coded line wire to terminal L2, and the red-coded ground wire to terminal 4G.
62. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line wire connections at the line-and-cord terminal block and repeat the test.
63. Remove the base plate and reverse the ringer terminals 5 and G; repeat the test.
64. Increase the tension of the ringer biasing springs; repeat the test.
65. By connecting at the terminal subassembly, the red-blue ringer wire to terminal L2, the line wires J90 and JJ95 to terminals L1 and L2 respectively, the ground wire J9 to terminal G, and the battery connected wire JJ9 to terminal B.
66. To operate an extension signal associated with the telephone when ringing current is sent out to the telephone.
67. To eliminate any possibility of the extension signal being actuated during dialing.
68. At the terminal subassembly, connect the red-blue ringer wire to terminal G, the ship's cable wires J95, JJ95, J9 and JJ9 to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G.

69. Move the power signal relay lead from the L1 to the L2 terminal and repeat the test.
70. By substituting a receiver known to be good for the receiver already in the handset.
71. Because the capsule cannot be opened without damage to the receiver.
72. Across terminals R and B.
73. Open relay coil or open capacitor.

Chapter 10

CLOSED CIRCUIT TELEVISION

1. Video, audio, and TV receiver.
2. Mosaic.
3. Video sync and blanking pulses.
4. Frequency modulation.
5. Video, audio, blanking, and sync signals.
6. The sync generator.
7. Image orthicon.
8. 3-foot-candles.
9. 525.
10. By using deflection coils.
11. Broad band-pass.
12. 15,750.
13. 15,750,000.
14. 7.87 mc.
15. 262.5
16. 60 times per second.
17. Equalizing pulses.
18. 875.
19. Positive.
20. Distortion of the picture.
21. By using a small inductor in series with the plate load.
22. It is removed from the pulse waveform by the action of the coupling capacitor.
23. By employing low- and high-pass filters respectively.
24. Sawtooth.
25. Multivibrators and blocking oscillators.
26. Electromagnetic.
27. They damp out spurious oscillations.
28. Flyback (or kickback).
29. Resonant voltage stepup.

Chapter 11

SHIP CONTROL ORDER AND INDICATING SYSTEMS

1. Synchro transmitter, receivers, or a combination of both.
2. Circuit 1MB (starboard) and circuit 2MB (port).
3. Wrong-direction signal contacts.
4. Throttle station 1.
5. Leading throttle stations.
6. Starboard and port sides, respectively, of the forward engineroom.
7. Following throttle stations.
8. On all indicators in the circuit.
9. By matching the reply pointer with the received order on the indicator-transmitter at the following throttle station.
10. On the single indicator in the leading throttle station.
11. On the double indicator-transmitter in the conning stations that originated the order and at the fireroom of each operating station.
12. The units in the enginerooms and boiler operating stations.
13. Propeller order indicator-transmitter.
14. To transmit and receive acknowledgement of engine orders for circuits 1MB (starboard) and 2MB (port).
15. A forward or aft movement of either transmitter operating handle selects AHEAD and BACK orders respectively on either the port or starboard dial.
16. The bells ring when the reply is received from the engineroom units.
17. Indicates the transmitted 2MB engine order from the conning station to the port throttles and the answer from throttle stations 4 after throttle station 3 has acknowledged the transmitted order.
18. The indicator and transmitter in the open bridge and the indicator in the pilot house.
19. The repeat-back to the indicator in fireroom 1.

20. The fireroom's indicator to the repeat-back when the secondary conning station is in control.
21. To transmit to the throttle stations, small changes in the number of propeller revolutions.
22. By turning the operating knobs of the propeller order indicator-transmitter until the digits in the transmitter sections correspond with those in the indicator sections of the three windows.
23. To close the alarm bell circuit causing a bell to ring on the engineroom unit.
24. To provide a repeat-back indicator system for the rudder order system.
25. On the combined rudder angle order indicator in the after steering station.
26. The reply from the rudder angle transmitters coupled to the respective port and starboard rudder heads.
27. To indicate transmitted rudder order from the conning station and the answer from the after steering stations when the positions of the rudders are changed to correspond with the transmitted order.
28. To transmit the actual positions of the rudders to indicators at the conning stations, after steering stations, and throttle station 1.
29. To indicate the actual positions of a starboard and a port rudder.
30. To provide an emergency signal from the conning station to the after steering station for shifting the steering control to the trick wheel in the steering gear room.
31. A contact maker controlled at each conning station, connected electrically to a siren in the after steering station.
32. Counterclockwise.
33. The voltage between the S1 and S3 leads must be zero and the phase of the voltage at S2 must be the same as the phase of the voltage at R1.
34. At the 0 degree and 180 degree positions of the rotor.
35. Less than the line voltage.

Chapter 12

SHIP'S METERING AND INDICATING SYSTEMS

1. Rpm, direction of rotation, and total revolutions.
2. They convert running speeds to angular synchro displacements.
3. It is indicated by the backing signal indicator which is lighted when the shaft rotates in an astern direction.
4. It is an automatic comparison device that is continuously self-adjusting to balance unknown propeller shaft speed against a fixed speed.
5. Contacts are open and the followup motor, 9, is deenergized.
6. A limiting switch deenergizes the synchronous motor, 4, in figure 12-4.
7. To convert the speed of the propeller shaft to a proportional d-c voltage.
8. To add propeller revolutions in both the ahead and astern directions of the propeller shaft.
9. A d-c voltmeter.
10. The rotor assembly.
11. Because wind directions are indicated in relative bearings.
12. When the CT and the direction transmitter are in correspondence.
13. It is fed to the input transformer, T1, of the amplifier.
14. They are connected in push-pull.
15. It positions the 5HG transmitter and drives the rotor of the CT into correspondence with the vane transmitter rotor to null the signal and stop the motor.
16. Rectifiers CR1 and CR2.
17. It depends on the position of the roller with respect to the center of the driving disks.
18. When the wind speed is zero.
19. To indicate the amount of salinity in water systems aboard ship.
20. That an increase of the electrolytic impurities in water increases the electrical conductivity of the water.
21. In equivalent parts per million.

22. One or more salinity cells and an indicator panel.
23. The inner electrode, adapter, automatic temperature compensator, and the outer electrode.
24. A flashing red indicator light and an audible alarm.
25. The conductance values of the salinity cell electrodes and compensator.
26. Pitot-static, electromechanical type, and electromagnetic type.
27. Rodmeter, sea valve, and indicator-transmitter.
28. The speed servo.
29. An error detector.
30. It provides degeneration.
31. From the full-wave rectifier CR1-CR2 and choke L3.
32. It is a 2-stage, half-wave self-saturating unit.
33. A 2-phase squirrel-cage induction motor.
34. To develop a continuous shaft rotation proportional to ship speed.
35. Like a variable transformer.
36. A bridge type.
37. To minimize transformer coupling.

Chapter 13

MAGNESYN COMPASS SYSTEM

1. A magnet.
2. Because the lines of force of the earth's field enter it.
3. Deviation.
4. Electromagnetic induction.
5. They vary with the rotor movement.
6. The voltages are unbalanced, and currents flow between the two stators, orienting the indicator field and rotor with those of the transmitter.
7. An annular magnetic core placed around the outside of the indicator stator.
8. Directly beneath the compass magnet.
9. In parallel.
10. Magnetic shield.
11. By a miniature shunt motor driving a permanent magnet rotor a-c generator.
12. In locations having a minimum of magnetic interference.
13. A test compass (direct reading).
14. To avoid undue swing as the vessel rolls and pitches.
15. By rotating the unit in its mounting slots.
16. Up to a total of three.
17. Because such reversal might cause failure of the system and serious damage to the instrument.
18. Whenever the ship gets underway.
19. At the end of each 500 hours of operation.
20. It might demagnetize the permanent magnet rotor of the a-c generator, resulting in greatly reduced output voltage.

Chapter 14

THE GYROCOMPASS

1. The tilt of the gyro rotor caused by the earth's rotation and the force of gravity.
2. Oil suspension.
3. The tilt is detected by a gravity reference (electrolytic bubble level).
4. The damping signal and the meridian signal.
5. From the cathode of V4B.
6. Meridian control signal, the latitude or vertical earth rate signal, and the balance correction signal.
7. The latitude switch alters the connection of the meridian control signal mixing resistors, R43 and R44, thereby changing the magnitude of the meridian control signal. The result is a 90 minute compass period at either a 45° or 65° latitude.
8. To permit the effects of mechanical imbalance to be corrected without actually making mechanical adjustments in the master gyrocompass.

9. To adjust and calibrate the vertical earth rate signal.
10. From the secondary of output transformer T6.
11. To match the impedance of the output stage to the tuned impedance of the series connected control fields of the azimuth control torquers.
12. By a negative feedback taken from a tap on the secondary of T6.
13. The azimuth control torquers.
14. They are 90 degrees out-of-phase.
15. Leveling amplifier, leveling torquer, and the speed corrector.
16. The damping signal and the speed correction signal.
17. The use of part of the output from the transformer to excite V6B along with the common cathode resistor produces the proper phase inversion.
18. The leveling torquer.
19. A phase sensitive demodulator.
20. Either in-phase or 180 degrees out-of-phase.
21. It would require a large voltage regulator.
22. Vertical earth rate correction, speed correction, and balance correction.
23. The stepped-down voltage of T3 is subtracted from the constant voltage drop across the series resistors and the difference is impressed on the primary of T4.
24. To drive the phantom bowl in azimuth, thus keeping the vertical ring and the plane of the gyro wheel in continuous alignment.
25. The rigidity of the gyro.
26. The phase of the signal voltage in relation to the input reference voltage.
27. Prevents a large momentary displacement between the pickoff and the gyrosphere.
28. From the center-tap of the modulator transformer T-10.
29. The direction depends upon the polarity of the signal from the amplifier and the speed upon the diaplacement between the fixed and control fields.
30. 115-volt a-c 400-cycle 3-phase, 115-volt a-c 400-cycle single-phase, and 115-volt a-c 400- or 60-cycle single-phase.
31. 2 hours.
32. Sectionalize the fault, and localize the fault.

Chapter 15

FRESNEL LENS OPTICAL LANDING SYSTEM

1. To maintain the deck edge assembly at a fixed angle with the horizontal regardless of pitch or roll.
2. In the gyrocompass stable element.
3. The control windings of Z2.
4. The tachometer.
5. An electrical signal representing the basic angle setting and the roll correction.
6. The 2- and 36-speed CT signals.
7. Near zero error.
8. In a direction that will make the output tend toward zero.
9. To remove power from the servo field.
10. By a mechanical differential.
11. The CDX and the TR.
12. The segment gear.
13. The phase voltage from Z2.
14. Power is removed from servo motor reference field and a short circuit is applied across the field.
15. It gives a visual indication of the position error of the servo system.
16. 115-volt a-c 60-cycle 3-phase.
17. By magnetic dimmers.
18. To select the remote control panel.
19. Directly across the line.
20. Power matching autotransformers.
21. Power matching and 115/60 step down voltage.
22. 12 volts per lamp.
23. K2 energizes and K2G closes.
24. The waveoff switch.
25. 180 degrees out-of-phase.

26. Meters, indicator lamps, and indicating fuses.
27. A circuit consisting of a sensitive relay driven by a current transformer.
28. No, just the actuating device.
29. Focal length changes with temperature.
30. The dimmer control rheostats.
31. The power panel must be de-energized.
32. A defective synchro.
33. A faulty tachometer.
34. Servo instability and failure to recover properly.
35. By a logical step-by-step procedure.
36. Those circuits that are common to several units.

APPENDIX II

TRAINING FILM LIST

Navy No.	Film title and description	Applicable to chapter(s)
MA-8581A	Servo Systems and Data Transmission, Part I-Fundamentals of Servo (17 min-B&W-Sound-Unclassified-1956) U. S. Army TF 11-2235 Defines the fundamental concepts of servo systems, and explains the functioning of the principle servo components. The components discussed include the input, controller, output, torque, and feedback.	15
MA-8581B	Servo System and Data Transmission, Part II-Basic Principles of Positioning Servos (33 min-B&W-Sound-Unclassified-1956) U. S. Army TF 11-2236 Considers positioning functions of servo. Illustrates the servo as a mechanically integrated operational system.	15
MC-1574	Light Waves and Their Uses (17 min-B&W-Sound-Unclassified-1945) Illustrates principles of light waves and rays, how light is refracted and reflected, and image formation in relation to concave and convex lenses.	8
MN-1540Q	Signal Generator Operation (9 min-B&W-Sound-Unclassified-1945) Use of signal generator in receiver alignment is discussed.	5, 7, 10
MN-1540R	Audio Oscillator Operation (9 min-B&W-Sound-Unclassified-1945) Explains audio oscillator and demonstrates its use. Shows how to check on amplifier with audio oscillator and "A" scope.	5, 6, 10
MN-1540W	Synchro Systems, Part I (15 min-B&W-Sound-Unclassified-1944) Shows how synchro transmitters can effect and control movement of synchro receiver.	14

Navy No.	Film title and description	Applicable to chapter(s)
MN-1540X	Synchro System, Part II (13 min-B&W-Sound-Unclassified-1944) Shows operation of control transformer and differential synchro transmitter. Includes various checks to be made in the process of troubleshooting.	14
MN-2104B	The Cathode Ray Oscilloscope (23 min-B&W-Sound-Unclassified-1944) Explains wide application of scope in making instantaneous graphs of the wave form of an electric current. Explains vertical and horizontal amplifiers, sweep generator, and power supply.	5, 10, 14
MN-7465A	Gyro Compasses Mk 19 Mod 3 and Mk 23–Earth Rate (17 min-B&W-Sound-Unclassified-1954) Shows how gravity works with the principles of rigidity, precession and earth rate to make a gyrocompass out of the gyroscope.	14
MN-7465B	Mk 19 Mod 3 Mk 23-The Gyro as a Compass (15 min-B&W-Sound-Unclassified-1954) Shows how the rotation of the earth causes apparent rotation of the gyroscope about its axis.	14
MN-7465C	Mk 19 Mod 3 and Mk 23–General Description (25 min-B&W-Sound-Unclassified-1954) Describes the five major components of the Mk 23. The function of these parts are also explained.	14
MN-7465D	Mk 19 and Mod 3 and Mk 23–Compass Control Mk 23 (15 min-B&W-Sound-Unclassified-1954) Describes the compass control system including the gravity reference, azimuth control, and leveling control.	14
MN-7465E	Mk 19 Mod 3 and Mk 23 (18 min-B&W-Sound-Unclassified-1954) Names the 3 correction signals in the compass control system and discusses each of them.	14
MN-7465F	Mk 19 Mod 3 and Mk 23-Followup System Mk 23 (13 min-B&W-Sound-Unclassified-1954) Describes followup system. Shows how different components of the system tie together.	14

Navy No.	Film title and description	Applicable to chapter(s)
MN-7465G	Operation and Maintenance Mk 23 (20 min-B&W-Sound-Unclassified-1954) Describes normal and directional gyro modes of operation. Explains procedure for starting and securing the compass. Outlines procedures for both preventive and corrective maintenance, including troubleshooting.	14
MN-8483A	Magnetic Amplifiers—Theory of Operation (18 min-B&W-Sound-Unclassified-1957) Presents the basic theory necessary for understanding magnetic amplifiers. Explains magnetic flux; the effect of open and closed cores, both rectangular and toroidal; and the effect of simultaneously using d-c and a-c windings on a closed core.	15
MN-8483B	Magnetic Amplifiers—Circuits and Applications (17 min-B&W-Sound-Unclassified-1957) Describes advantages of magnetic amplifiers and gives examples of their use. Describes the effects of adding rectifiers, "cross-over" windings, resistors, and feedback windings.	15
MN-8494	Optical Landing System (12 min-B&W-Sound-Unclassified-1958) This film demonstrates to carrier pilots the principles of operational technique of landing on a carrier using Optical Landing System.	15
SN-62A	Interior Communications—Battle Announcing Equipment-DD (23 min-81 frames-B&W-Sound-Unclassified-1943) Briefly explains equipment. Demonstrates in detail proper method of using it.	5
SN-62B	Interior Communication—Battle Announcing Equipment—Submarine (26 min-83 frames-B&W-Sound-Unclassified-1944) Use of the class A-type transmitter is demonstrated. Alarm system is also explained.	5

Navy No.	Film title and description	Applicable to chapter(s)
SN-62C	Interior Communication–Battle Announcing Equipment–Carriers (29 min-115 frames-B&W-Sound-Unclassified-1943) Explains relationship of amplifier, microphone, and reproducer. Explains priority system. Demonstrates how to use the system.	5
SN-62D	Interior Communication–Battle Announcing Equipment–Battleships, Cruisers, and Auxiliaries (30 min-108 frames-B&W-Sound-Unclassified-1944) Explains basic operating principles. Demonstrates how the system operates.	5
SN-62E	Interior Communications–Battle Announcing Equipment–Maintenance (40 min-124 frames-B&W-Sound-Unclassified-1944) Describes various types of equipment (from 1MC to 17MC) available for fleet use. Explains signal generators. Demonstrates maintenance procedures and troubleshooting techniques.	5
SN-62F	Electrical Telegraph System, Part I (13 min-48 frames-B&W-Sound-Unclassified-1943) Explains use in transmitting orders for the proper control of the ship. Shows parts, functions, location, and the cycle of operation of the 1MB and 2MB.	11
SN-62G	Electrical Telegraph System, Part II (10 min-43 frames-B&W-Sound-Unclassified-1943) Explains how indicator operates; stresses necessity for care and maintenance; demonstrates how to inspect, replace, and synchronize parts.	11
SN-62L	Wind Direction and Intensity Indicating and Recording System (19 min-59 frames-B&W-Sound-Unclassified-1942) Explains operation of system. Names various parts of system.	12

Navy No.	Film title and description	Applicable to chapter(s)
SN-62P	Ship Service Telephone (24 min-85 frames-B&W-Sound-Unclassified-1943) Line station equipment, nomenclature of A-, B-, and C-type line stations, automatic switchboard, and power equipment are illustrated. Station call is traced through all circuits.	9
SN-62Q	Ship Service Telephone (20 min-68 frames-B&W-Sound-Unclassified-1943) Attendants cabinet is illustrated; testing, maintenance, troubleshooting, replacing and adjusting equipment are demonstrated.	9
SN-62X	Wind Direction and Intensity Indicating Equipment (14 min-61 frames-B&W-Sound-Unclassified-1944) Shows transmitter unit, consisting of anemometer and wind vane, connected by gears to electrical equipment. Emphasis is on wind intensity section.	12
SN-62Z	Shaft Revolution Equipment (15 min-71 frames-B&W-Sound-Unclassified-1943) Shows details of operation of transmitter, indicator, counter, and frequency control unit.	12
SN-62AA	Shaft Revolution Equipment (15 min-54 frames-B&W-Sound-Unclassified-1943) Shows I.C. distribution board and ACO switchboard. Describes how tachometer generates voltage.	12
SN-62AB	Salinity Indicating Equipment (22 min-74 frames-B&W-Sound-Unclassified-1943) Explains damage of salt in engineering system. Describes indicator panel, procedure for checking, repairing, cleaning, and disassembly of equipment.	12

Navy No.	Film title and description	Applicable to chapter(s)
SN-624	Wind Direction and Intensity Indicating Equipment (11 min-49 frames-B&W-Sound-Unclassified-1944) Shows wind direction master transmitter with its roll, cam, disk, and followup motor. Also shows operation of the system.	12
SN-650	Vacuum tubes (37 frames-B&W-Silent-Unclassified-1942) Describes theory of operation of vacuum tubes and function in the radio circuit.	4, 10
SN-652	Audio Frequency Amplification (25 frames-B&W-Unclassified-1942) Describes theory and practice of audio wave amplification.	4, 5, 6, 7, 8 and 10
SN-654	Reproducers (29 frames-B&W-Silent-Unclassified-1942) Describes change of sound waves to electrical impulses, to radio waves, and back to sound waves. The dynamic-type loudspeaker is shown.	4
SN-4090A	Fundamentals of Sound, Part I (15 min-74 frames-B&W-Sound-Unclassified-1944) Demonstrates generation of sound waves by vibrating bodies. Explains terms such as cycle, hearing, and frequency. Discusses range of hearing.	3, 8
SN-4090B	Fundamentals of Sound, Part II (15 min-71 frames-B&W-Sound-Unclassified-1944) Deals with speed of sound, refraction, reflection, and doppler effect.	3, 8

APPENDIX III

QUALIFICATIONS FOR ADVANCEMENT IN RATING

INTERIOR COMMUNICATIONS ELECTRICIAN (IC)

Quals Current Through Change 17

General Rating

Scope

Interior Communications Electricians: Maintain and repair interior communications (IC) systems, gyrocompass systems, amplified and unamplified voice systems, alarm and warning systems, and related equipment; stand IC and gyrocompass watches.

Service Ratings

None.

Path of Advancement to Limited Duty Officer

Interior Communications Electricians advance to Limited Duty Officers, Electrician.

Navy Enlisted Classification Codes

See Manual of Navy Enlisted Classifications, NavPers 15105B.

Qualifications for Advancement in Rating

1. Qualifications for advancement to a higher rate include the qualifications of the lower rate or rates in addition to those stated for the higher rate.
2. Practical factors will be completed before recommendation for participation in the advancement examination. (Bureau of Naval Personnel Manual, NavPers 15791A, Articles B-2326 and C-7201.)
3. Knowledge factors and knowledge aspects of practical factors will form the basis for questions in the written advancement examination.

Qualifications for Advancement in Rating	Applicable Rates IC
A. THEORY OF ELECTRICITY, ELECTRONICS	
1.0 PRACTICAL FACTORS	
1. Interpret RETMA color coding of: capacitors, resistors, internal connections of power and audio transformers, and chassis wiring	3
2.0 KNOWLEDGE FACTORS	
1. Meaning and/or significance of terms such as:	
a. Volt	3
b. Ohm	3
c. Ampere	3
d. Watt	3
e. Volt-ampere	3
f. Henry	3
g. Farad	3
h. Cycle	3
i. Ampere-turn	3
j. Conductor and insulator	3
k. Flux density	3
l. Permeability	3
m. Electromagnetic induction	3
n. Power factor	3
o. Frequency	3
p. Phase	3
q. Amplifier	3
r. Hysteresis and eddy current	3
s. Reactance	3
t. Impedance	3
u. Capacitance	3
v. Inductance	3
w. Magnetic lines of force	3
x. Coulomb	3
y. Circular mil	3
z. Horsepower	3
aa. Torque	3
bb. Ambient temperature	3
cc. Gain	2
dd. Feedback	2
ee. Bias	2
ff. Cutoff	2
gg. Plate current	2
hh. Grid current	2
ii. Electron-tube characteristics	2
jj. Phase distortion	2
kk. Amplitude	2
ll. Transistor characteristics	2

Qualifications for Advancement in Rating	Applicable Rates IC
A. THEORY OF ELECTRICITY, ELECTRONICS—Continued	
2.0 KNOWLEDGE FACTORS—Continued	
2. Relationship of current, voltage, and resistance in d.c. circuits	3
3. Relationship of current, voltage, and impedance in a.c. circuits	3
4. Relationship of reluctance, flux, and magnetomotive force (m.m.f.) in a.c. and d.c. magnetic circuits	3
5. Relationship of resistance, temperature, and current in an electrical conductor	3
6. Relationship of length and cross-sectional area to resistance of a conductor	3
7. Functions and operating principles of:	
a. Electron (diode and triode) tubes used in IC equipment	3
b. Electron, gas-filled, and cathode-ray tubes	2
c. Transistors and diodes	2
8. Construction of electron tubes, gas-filled tubes, transistors, and diodes, and cathode-ray tubes used in IC equipment	2
9. Methods of coupling amplifier stages: transformer impedance, capacitive, resistive, and direct	2
10. Characteristics and use of synchros; methods of setting to electrical zero; purpose of gain, phase, and balance adjustments	2
B. EQUIPMENT DEVICES AND SYSTEMS	
1.0 PRACTICAL FACTORS	
1. Energize and start, test for proper operation, operate and secure, ship's metering and indicating systems, ship's control systems, alarm and warning systems, signal systems, gyrocompass and associated equipment, and amplified voice and projection equipment	3
2. Cross-connect IC systems to operate under battle, emergency, and casualty conditions	2
3. Effect authorized field changes to IC equipment in accordance with instructions and diagrams	1

Qualifications for Advancement in Rating	Applicable Rates IC
B. EQUIPMENT DEVICES AND SYSTEMS—Continued	
2.0 KNOWLEDGE FACTORS	
1. Construction and operating principles of power units such as motor-generator sets, control panels, transformers, and rectifiers of IC equipment	3
2. Construction and principles of operation of IC systems:	
a. Underwater log	3
b. Wind indicators	3
c. Central-amplifier announcing systems	2
d. Gyrocompasses	2
e. Optical landing system	2
f. Magnesyn compass system	2
g. Automatic telephones	1
h. Closed-circuit television	1
i. Communication console	1
C. MAINTENANCE	
1.0 PRACTICAL FACTORS	
1. Make tests for, locate, and clear short and open circuits and grounds in cables, wiring, fittings, buzzers, call bells, and other simple circuits	3
2. Inspect, clean, and lubricate IC equipment in accordance with technical maintenance publications	3
3. Make complete casualty analysis and repair of sound-powered telephone handsets and headsets	3
4. Use and perform preventive maintenance on the following test equipment:	
a. Nonelectronic volt-ohm-ammeter	3
b. Electronic volt-ohm-ammeter	3
c. Tube tester	3
d. Megger	3
e. Tachometer	3
f. Circuit analyzer	2
g. Oscilloscope	2
h. Signal generator	2
5. Test, repair, and/or replace parts such as relays, plugs, lamps, fuses, switches, tubes, jacks, cables, wiring, fixed capacitors, variacs, transformers, fixed resistors, and potentiometers within a component, assembly, or subassembly	2

Qualifications for Advancement in Rating	Applicable Rates IC
C. MAINTENANCE—Continued	
1.0 PRACTICAL FACTORS--Continued	
6. Localize casualties and perform corrective maintenance on the following:	
a. Alarm and warning systems including toxic vapor and contaminated air systems	3
b. Voice recorders and record players	2
c. Sound motion picture projectors (16 mm.). . .	2
d. Intercoms and portable announcing systems .	2
e. Ship-control order and indicating system . . .	2
f. Ship order and indicating units (synchro) . . .	2
g. Motor-generator sets and control panels as applied to IC equipment.	2
h. Central amplifier system.	2
i. Underwater logs.	2
j. Wind indicators	2
k. Magnetic amplifiers	2
l. Sound-powered telephone circuits	2
m. Optical landing system	2
n. Magnesyn compass.	2
o. Constant frequency control	2
p. Automatic telephones	2
q. Gyrocompass and associated navigation equipment such as dead-reckoning analyzer (DRA), dead-reckoning tracer (DRT), gyrorepeaters, and synchro-amplifiers.	1
r. Self-synchronous alidades	1
s. Closed-circuit television.	1
t. Communication console.	1
u. Synchro-amplifier	1
7. Make tests, adjustments, and repairs necessary for proper operation of synchro-control circuits including servoloops	1
8. Test, remove, and install meters and instrument transformers	1
9. Make periodic inspections and internal adjustments of IC units	1
10. Localize casualties to parts or subassemblies of IC equipment; repair by replacement of subassemblies or parts.	1
11. Test and evaluate new or overhauled components, assemblies, or subassemblies of IC equipment for proper and secure installation and optimum performance	C
12. Analyze and evaluate electrical and electronic tests; make adjustments, calibrations, and repairs for optimum performance of IC equipment . .	C

Qualifications for Advancement in Rating	Applicable Rates IC
C. MAINTENANCE—Continued	
2.0 KNOWLEDGE FACTORS	
1. Procedures for replacing electron tubes, transistors, and diodes	3
2. Casualty analysis and corrective maintenance for the following IC equipment:	
a. Cables, wiring, and fittings	3
b. Sound-powered telephone handsets and headsets	3
3. Lubricants, cleaning materials, and solutions used, and safety precautions to be observed in their use, in the maintenance of IC equipment	3
4. Methods and equipment used in electrical tests for continuity, grounds, and short circuits	3
5. Preventive maintenance for, function of, and operating procedures in using the following:	
a. Nonelectronic volt-ohm-ammeter	3
b. Electronic volt-ohm-ammeter	3
c. Tube tester	3
d. Megger	3
e. Tachometer	3
f. Circuit analyzer	2
g. Oscilloscope	2
h. Signal generator	2
6. Theory of operations of magnetic amplifiers	2
D. MOTORS, GENERATORS, AND RELATED EQUIPMENT	
1.0 PRACTICAL FACTORS	
1. Inspect and clean commutators and slipring assemblies and observe safety precautions	3
2. Replace and adjust brushes on commutators and slipring assemblies	2
2.0 KNOWLEDGE FACTORS	
1. Construction of motors, generators, and alternators; application of laws of magnetism to electric rotating machinery	2
2. Methods and procedures for adjusting voltage regulators	1

Qualifications for Advancement in Rating	Applicable Rates IC
E. CABLES AND CONNECTIONS	
1.0 PRACTICAL FACTORS	
1. Renew section of cable between:	
a. Junction boxes	3
b. Junction boxes and equipment	3
2. Connect casualty powerlines	3
3. Make electric connections and splices including soldered joints and pressure-type terminals (solderless type)	3
4. Identify by marking systems electric cables, wiring, and fittings	3
5. Install necessary leads for connecting a synchro-generator to independent synchromotors through a rotary switch	2
2.0 KNOWLEDGE FACTORS	
1. Construction, types, and uses of shipboard electric cable	3
2. Normal, alternate, and emergency-power distribution sources for shipboard lighting and IC power	3
F. SWITCHBOARDS	
1.0 PRACTICAL FACTORS	
1. Operate IC switchboards:	
a. Transfer circuits for normal, battle, emergency, and casualty conditions	3
b. Set up control circuits for anchor and underway conditions	3
2. Tighten connections on switchboards and control panels	3
2.0 KNOWLEDGE FACTORS	
1. Procedures for energizing, testing, proper operation of, transferring control of, and securing IC circuits and equipment on IC switchboards for normal, battle, emergency, and casualty conditions	3
2. Methods and procedures for overhaul of IC switchboards	1

Qualifications for Advancement in Rating	Applicable Rates IC
G. CIRCUITS AND DIAGRAMS	
1.0 PRACTICAL FACTORS	
1. Read schematic and wiring diagrams, IC technical-maintenance publications, and installation blueprints; identify and interpret electric, electronic, and mechanical symbols shown in schematic and wiring diagrams, IC technical-maintenance publications, and installation blueprints	3
2. Test IC circuits that are external to major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values.	3
3. Test internal circuits of major units of IC equipment for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, and power, and compare with established values; use an oscilloscope to view circuit waveforms and compare with established optimum-performance waveforms required in IC equipment.	2
4. Prepare diagrams and sketches of IC devices and equipment, using standard designations for cables, wiring, terminal markings, and circuit components	C
2.0 KNOWLEDGE FACTORS	
1. Types of information shown and meaning of electric, electronic, and mechanical symbols used in equipment schematic diagrams and wiring diagrams, block diagrams, IC technical maintenance publications, and installation blueprints	3
2. Calculate current, voltage, and resistance in d.c. series and parallel circuits of not more than four elements	3
3. Function of component parts in IC electric and electronic circuits such as:	
a. Resistors	3
b. Rheostats	3
c. Potentiometers	3
d. Solenoids	3
e. Inductors	3
f. Capacitors	3
g. Fuses	3
h. Switches	3

Qualifications for Advancement in Rating	Applicable Rates IC
G. CIRCUITS AND DIAGRAMS—Continued	
2.0 KNOWLEDGE FACTORS—Continued	
i. Transformers	3
j. Relays	3
k. Saturable reactors	2
l. Transistors	1
4. Methods of obtaining three general types of bias: fixed, cathode, and grid leak.	2
5. Principles of IC polyphase circuits	2
6. Function and operating principles of the following circuits:	
a. Audioamplifier.	2
b. Rectifier	2
c. Transistor	1
7. Daily, weekly, monthly, quarterly, semiannual, and annual tests required on IC circuits and equipment	1
H. MATERIALS AND EQUIPMENT	
1.0 PRACTICAL FACTORS	
1. Select, use, and maintain electrician's common hand and small bench tools including soldering irons and electric-powered tools such as drills and grinders provided for maintenance and repair of IC equipment	3
2. Inspect, maintain, test, and install storage and dry-cell batteries.	3
2.0 KNOWLEDGE FACTORS	
1. Care and storage of IC materials	3
2. Types and purposes of handtools and small portable power tools provided for maintenance and repair of IC equipment.	3
3. Types and identification of insulating materials and varnishes.	3
4. Soldering equipment and methods used in maintenance and repair of IC equipment	3
5. Types, structure, and electrical characteristics of batteries	3
I. SUPPLY PROCEDURES	
1.0 PRACTICAL FACTORS	
1. Obtain parts and stock numbers from technical and supply publications and prepare requisitions for tools and replacement parts	3

Qualifications for Advancement in Rating	Applicable Rates IC
I. SUPPLY PROCEDURES—Continued	
1.0 PRACTICAL FACTORS—Continued	
2. Take, record, and report inventories of tools and portable test equipment available for maintenance and repair of IC equipment	2
2.0 KNOWLEDGE FACTORS	
1. Accounting procedures for IC equipment, maintaining control of inventories and workflow, and reporting equipment status and work accomplished	C
J. REPORTS, PUBLICATIONS, AND RECORDS	
1.0 PRACTICAL FACTORS	
1. Maintain all required records at watch station	3
2. Use electrical publications for selecting materials and identifying equipment parts	3
3. Locate and identify by reference to technical maintenance publications, block diagrams and installation blueprints, components, assemblies, subassemblies, and primary and casualty power circuits of IC equipment	3
4. Prepare job orders and work requests for both tender and shipboard repairs to IC or gyrocompass equipment	1
2.0 KNOWLEDGE FACTORS	
1. Types of entries and information recorded in IC equipment failure reports, work logs, equipment histories, checkoff lists, and current ship's maintenance project (CSMP)	3
2. Types of information reported in periodic or recurring reports concerning performance and maintenance of IC equipment	1
K. ADMINISTRATION, SUPERVISION, AND TRAINING	
1.0 PRACTICAL FACTORS	
1. Supervise setting up of public-address systems	2
2. Take charge of gyrocompass and IC watches	2
3. Supervise the underway watch in the IC room of a large combat vessel	1

Qualifications for Advancement in Rating	Applicable Rates IC
K. ADMINISTRATION, SUPERVISION, AND TRAINING—Continued	
1.0 PRACTICAL FACTORS—Continued	
4. Plan, organize, and direct work of personnel operating, maintaining, and repairing IC and gyrocompass systems	C
5. Estimate time, materials, and labor required for repair of IC systems and equipment	C
6. Supervise and train personnel in operation, maintenance, and repair of IC and gyrocompass equipment	C
2.0 KNOWLEDGE FACTORS	
1. System of assigning of "AN" letter-number combinations as designation for IC equipment	3
L. SAFETY PRECAUTIONS, FIRST AID, AND FIREFIGHTING	
1.0 PRACTICAL FACTORS	
1. Rescue a person in contact with an energized circuit; resuscitate a person unconscious from electric shock; treat for electric shock and burns. (Simulated conditions.)	3
2. Demonstrate and observe while servicing equipment, safety precautions such as tagging switches, removing fuses, grounding test equipment, using shorting bar and rubber mats	3
3. Extinguish electric fires, using CO_2 extinguishers. (Simulated conditions.)	3
2.0 KNOWLEDGE FACTORS	
1. Electrical and electronic safety precautions including those set forth in Chapter 18, U.S. Navy Safety Precautions (OPNAV 34P1), to be observed in servicing IC equipment.	3
2. Effects of electric shock, methods of resuscitation of a person unconscious from electric shock, and treatment for electric and acid burns	3

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